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New Scientist
HAVE WE GOT THE STONE AGE WRONG?
The audacious idea that plants, not rocks, sparked humanity's knack for invention

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Mysteries of the mind

What is really going on inside the lump of interconnected tissue within your skull? Join six pioneering researchers who will illuminate the neural underpinnings of thought, emotion and communication. Gain insights on topics such as the effects of screen time and explore strategies to optimise brain performance on 7 December at London's Congress Centre.

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Monarch butterfly migration: Mexico

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Podcast

Weekly

The team take a deep look at the microbiome and what we know about how to nurture it. Hear updates from the United Nations COP16 biodiversity summit in Colombia and find out about the upcoming COP29 climate meeting in Azerbaijan. Plus, what the results of this week's US elections may mean for climate change.

newscientist.com/nspod

BRIAN OVERCAST/ALAMY

Incredible journey Every year, millions of butterflies fly to Mexico

ESA/WEBB/NASA/CSA/STSCI

Into the void Why is there something rather than nothing?

Video

Depicting breast cancer

The Renaissance artist Michelangelo appears to have painted a woman with breast cancer in his fresco *The Flood* on the ceiling of the Sistine Chapel, which may have been a message about the inevitability of death. Michelangelo had carried out human dissections, which may have led him to include women with breast cancer in his pieces.

youtube.com/newscientist

Newsletter

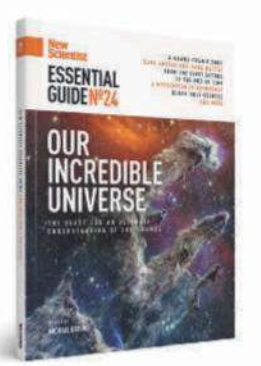
Lost in Space-Time

Kelsey Johnson, an astrophysicist at the University of Virginia, explores why the universe has something instead of nothing. She delves into the different types of nothing, involving quantum fields and black holes, to reveal how science has led us to the precipice of answering this existential mystery.

newscientist.com/lost-in-space-time

Podcast

"The WHO estimates that we spend $4 trillion on losses to extreme weather"



Essential guide

From tremendous chains of galaxies to supermassive black holes, our universe is a place of grandeur and spectacle. Find out how we are probing the cosmos like never before in this 24th *Essential Guide*. Available to download in the *New Scientist* app or to purchase in print from our shop.

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If we are serious about net zero, why are we opening new oil & gas fields?

Here's why.

You may ask whether a company that continues to produce more oil and gas is really committed to the energy transition. And it's a fair question, when you consider that 99.6% of our global energy production is in fossil fuels.

Today, oil and gas operations account for around 15% of total energy-related emissions globally. And yet we continue the search for oil and gas. Indefensible, some would say. The way we see it, it's the responsible thing to do.

Why? Well, last year saw record levels of renewable energy production, but we also experienced record demand for oil and gas. Even the most optimistic forecasts say that the world will still need oil and gas for decades to come. So it's important we keep investing in both renewables and oil and gas, to help create a more balanced and secure energy system.

But is it possible to speed up the transition? Well, that's what we're working on and it's one of the reasons our gross spend was a record 2.9 billion US dollars on renewables and lower carbon solutions last year. That's 20% of our global gross investments, compared to 14% the year before.

Our ambition is that our investments in profitable renewables and lower carbon solutions will reach 50% of our annual gross expenditure in 2030.

But if oil is going to be part of the bigger picture for decades to come, how we run our business matters. That's why we're always searching for better ways to produce it. Already, we have some of the lowest oil and gas production emissions in the world, but we still emit 11.6m tonnes of CO_2 a year. By 2030, we aim to make a net 50% reduction in these emissions (compared to 2015 levels) to 7.7m tonnes.

And we'll keep searching for better ways to do everything, across all of our business, from innovations to new technology. Every small solution helps towards solving the bigger picture. That's why we will always keep searching for better.

An energy company searching for better.

equinor.co.uk

Avoiding armageddon

Preparing for an asteroid strike can teach us about more immediate concerns

WHEN it comes to natural disasters, most are impossible to predict more than a few months or even days ahead of time – you can't say "an earthquake is going to hit in two years, let's prepare". However, one of the few for which we can be truly ready is an asteroid strike.

While nobody has found any large asteroids on a collision course with Earth yet, scientists, engineers and policy-makers are working on planetary defence plans for when we do. Disaster-averting techniques are already being tested, like giving asteroids a bump to change their trajectory, as NASA's Double Asteroid Redirection Test mission did successfully in 2022.

One surprisingly useful tool in the planetary defence tool belt is running role-playing games, which can reveal the stumbling blocks that could scupper even the best laid plans. Paul Chodas at NASA, who runs some of these exercises, says they uncover problems we never would have thought of otherwise. On page 40, you can try such a game for yourself.

"Compared with other existential threats, the risks from an asteroid are relatively small"

It should come as no surprise that factors like an incoming space rock's size and how early we spot it play a big role in whether we will successfully avoid disaster, but so too does our ability to collaborate on a global scale and effectively communicate the risks of different options. These are important lessons that go beyond just defending ourselves against asteroids.

Compared with other existential threats, the risks from an asteroid heading our way are relatively small. Climate change is already happening. Pandemics have occurred regularly throughout human history – and are made more likely by our warming planet. We know these come with technical challenges, like the development and rollout of green technologies, but the social ones are just as important.

It is only with effective global collaboration and communication that humanity can tackle its biggest problems. That is just as true in an asteroid role-playing game as it is in reality. ▮

PUBLISHING & COMMERCIAL
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CONTACT US
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UK 9 Derry Street, London, W8 5HY
Australia 58 Gipps Street, Collingwood, Victoria 3066
US 600 Fifth Avenue, 7th Floor, NY 10020

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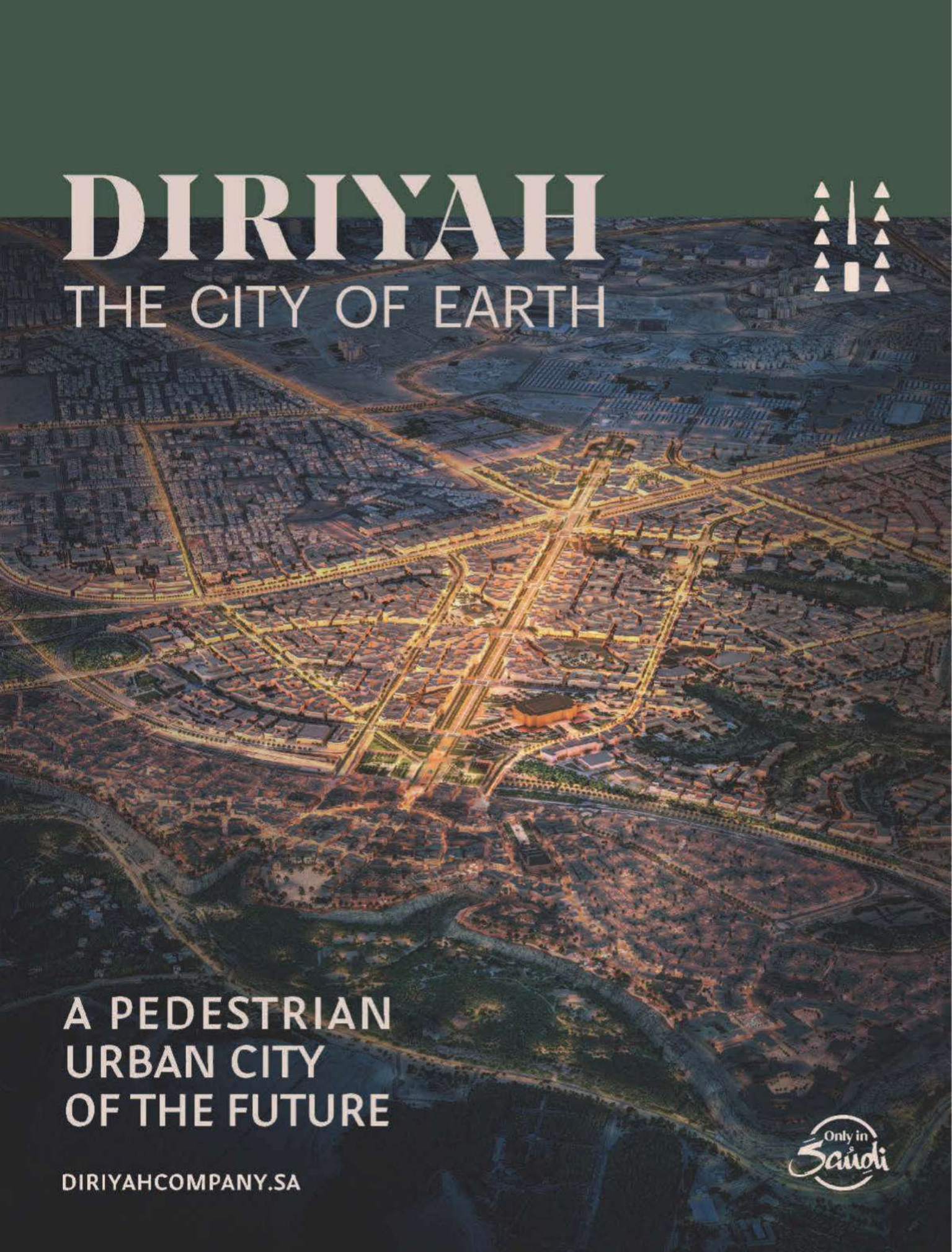
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Space

A world in a bubble

It might look like a planet, but this dazzling sphere was actually crafted on the International Space Station. In the microgravity of the ISS, water doesn't fall in drops. Instead, it forms spheres because they have the least possible surface area. To create this colourful, Jupiter-like effect, NASA astronaut Don Pettit injected a floating sphere of water with food colouring.

NASA JOHNSON

Physics

Is there a cosmic speed limit on growth?

Alan Turing's theories on computation seem to have a startling consequence – placing restrictions on how fast or slow anything in the universe can grow, finds **Karmela Padavic-Callaghan**

A NEWLY proposed cosmic speed limit may constrain how fast anything in the universe can grow. Its existence follows from Alan Turing's pioneering work on theoretical computer science, which opens the intriguing possibility that the structure of the universe is fundamentally linked to the nature of computation.

"The limit would apply to anything you can measure, including mass, energy and even time intervals"

Cosmic limits aren't a new idea. While studying the relationship between space and time, Albert Einstein showed that nothing in the universe can exceed the speed of light, as part of his special theory of relativity. Now, Toby Ord at the University of Oxford is proposing a new physical limit based on computation.

"I had the seed of this idea more than 20 years ago," he says. "It would apply to any quantity you can directly measure, including mass, charge, energy, etc., and even more subtle things like the time intervals between a sequence of events."

While devices like laptops and smartphones grow more powerful over time thanks to technological advances, we know that there are theoretical limits to computation – in particular, that some problems are "undecidable", meaning that no algorithm can answer them, no matter how powerful the computer.

One important example of this in the history of computer science is the halting problem, which asks whether a particular computer program will ever finish running or run forever. In the 1930s, Alan Turing and other researchers showed that the halting problem is undecidable.

They used a mathematical model of computation that has since become known as the Turing machine, and contemporary computer scientists broadly agree that if a problem is undecidable by a Turing machine, then it will also be impossible for any real, physical computer to tackle.

Ord is now proposing that the halting problem implies a physical limit for the growth of anything in the universe. To make the connection, he turned to another peculiar piece of mathematics called the Busy Beaver function, which tells you the longest time that a Turing machine can run, but still stop, depending on how many states it has, also known as its size.

As you consider larger and larger machines, this function grows extraordinarily quickly – its first two values are 1 and 6, but its fifth value is 47,176,870. The next value was recently proven to exceed a number so staggeringly large that it is difficult to express in standard mathematical notation. Written $10\uparrow\uparrow15$, it is 10 raised to the power of 10 repeatedly to create a "power tower" of 15 10s.

Because of its definition, any physical process that grows faster than the Busy Beaver function could be used to compute the halting function, which researchers think is impossible. Ord realised that this impossibility may be a two-way street.

"I turned this around, noticing that if the Turing machine really is the limit on what is computable in our universe, there must be no directly measurable quantities that grow this fast," he says.

In other words, the Busy Beaver function just may be the ultimate cosmic limit on how fast any physical process or system can grow – because a physical process that grows faster could be used to solve the halting problem, which ought to be incomputable.

Ord's limit wouldn't just apply to very fast-growing processes, but also very slow ones, using what Ord calls the Sleepy Sloth function (see diagram, left). This slowness is tied to Busy Beaver's values, so Sleepy Sloth starts at 1 and only reaches 5 as its 47,176,870th value.

"It is somewhat intuitive that there is an upper limit to how quickly things can grow, but surprising that there is also a limit on how slowly they can grow," says Ord.

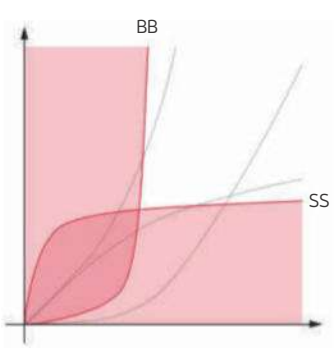
It is unlikely that anything in the universe would actually brush against either of these limits, but he says that it is a situation similar to the speed of light, where the fact that a limit exists at all may reflect something fundamental about the universe (arxiv, doi.org/nqb9).

Scott Aaronson at the University of Texas at Austin says that while computer scientists have long been interested in theoretical implications of the Busy Beaver function, Ord's work demonstrates how it may also connect to the physical world.

Edwin Beggs at Swansea University in the UK says that one difficulty with the new argument may lie in how we would measure and characterise a physical process that grew faster than Busy Beaver, given its incomputability.

Time to grow

The Busy Beaver (BB) and Sleepy Sloth (SS) functions grow extremely fast and slowly, respectively. They may also place limits on which growth rates are physically possible in the universe, meaning that any other function must eventually leave the red shaded regions to avoid breaking these limits.



Insights gleaned from computation may imply physical limits on growth

Beyond the limit

That means there could be something that breaks Ord's proposed cosmic limit, but we would struggle to recognise it as doing so. "I think there still is a hope of breaking this speed limit, but we would need to have some physical phenomenon that we knew about and that we actually knew could give us that boost," says Beggs.

TERRENCE COOK/500PX/GETTY IMAGES

Even if Ord is ultimately proved wrong, the connections between the physical world and Turing's ideas have been puzzling researchers for almost a century, and will continue to do so, says John Tucker, also at Swansea University. "The mathematics is sufficiently intriguing to warrant an enormous effort to keep pounding away at different perspectives," he says.

For Ord, one of those other perspectives may be to push back on the idea of limits of computability themselves. Ideas about Turing machines have been taken as settled for decades, but they are still mostly very strong hypotheses rather than irrevocably proven facts. If their repercussions are as dramatic as introducing new limits on physical reality, this raises the stakes on re-examining them and proving them more rigorously – lest we misunderstand the cosmos at large. "They may be less innocuous than we'd thought," says Ord. ▮

Environment

Clashes over cash are set to dominate COP29 climate talks

Madeleine Cuff

THOUSANDS of delegates from almost every country on Earth will arrive in Baku, Azerbaijan, for the annual United Nations Climate Change Conference, starting on 11 November.

These climate summits, known as Conferences of the Parties (COPs), are notorious for technical jargon and disputes over who should bear responsibility for rising emissions. Beyond the bluster, the stakes are real. With global average temperatures expected to exceed 1.5°C above pre-industrial levels for the first time this year and global emissions still rising, time is running out to meet the goals of the Paris Agreement.

Azerbaijan might seem a strange choice of host for a climate summit. Fossil fuels account for more than 90 per cent of its total exports and its emissions reduction plan is judged "critically insufficient" to meet international goals. But UN rules state this year's summit was to be held in eastern Europe, and with Russia blocking European Union countries from hosting, Azerbaijan's bid won.

"There's been a lot of contention around Azerbaijan's presidency," says Ruth Townend at the UK think tank Chatham House. "Going into a COP with that level of contention... doesn't bode well for its strong leadership."

COP29 is being billed as a finance COP, and top of the agenda is getting countries to agree to a climate finance target termed the New Collective Quantified Goal (NCQG). This is a commitment for high-income countries to help lower-income nations cut emissions and adapt to the impacts of climate change in the form of grants, loans and private finance.

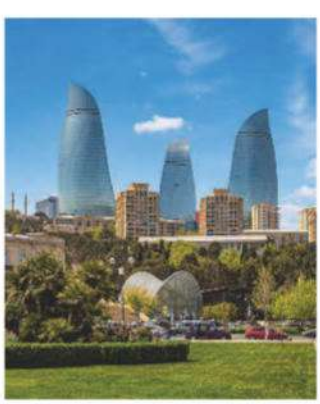
The new target will replace the $100 billion a year agreed by countries in 2009, a pledge that was finally met, two years late, in 2022. This time, lower-income countries want a finance target in the region of $1 trillion a year, starting in 2025.

A row is already brewing over who pays into this finance pot. The $100 billion goal was delivered by Annex II countries, those deemed industrialised by the UN. This excludes nations such as the Gulf States and China, which have rapidly developed in the past three decades and are now major emitters.

The US and EU are among the parties arguing the donor base for UN climate finance should be expanded to cover major polluters, but that is likely to meet fierce opposition. There are also suggestions that carbon taxes and levies on fossil fuel company profits could be leveraged to meet the NCQG.

By the end of the summit, the aim is to decide how much finance is being targeted and who pays. Yet nations are far from a consensus, according to Rob Moore, a former climate finance negotiator for the UK government, now at UK think tank E3G. "It is quite concerning that so close to the COP itself, we have not seen a high-level political movement towards convergence on what the goal will look like," he told a meeting of reporters in October.

Baku, the capital of Azerbaijan, is hosting the COP29 meeting



SHUTTERSTOCK/KADAGAN

Current climate plans, known in UN jargon as Nationally Determined Contributions (NDCs),

$1tn
a year has been called for as a climate finance goal

put the world on course for 2.6 to 3.1°C of warming by the end of the century, well above the 1.5 to 2°C goal of the Paris Agreement.

There is an opportunity to get back on track: by February 2025, all countries must submit new climate plans to the UN detailing how far they will cut emissions by 2035. It is likely to come down to money, however.

"If developing countries don't get a good agreement on finance, they're unlikely to produce strong, 1.5°C-compliant NDCs," says Townend. "While this COP might be seen by some as a smaller, more technical COP, it really is about that enabling finance, without which everything falls apart."

Azerbaijan wants the focus of COP29 to be on climate finance. But the last four COP meetings have been dominated by debate over the need to phase out fossil fuels. At last year's summit in Dubai, nations collectively agreed to "transition away from fossil fuels in energy systems".

Many campaigners would like to see this fossil fuel language strengthened, but aren't too optimistic given the world's current unstable geopolitics. ▮

Environment

Winter ice is rapidly vanishing from lakes

Rachel Nuwer

LIKE melting sea ice and glaciers, the frozen sheets that cover lakes are vanishing. Lake ice loss has accelerated over the past 25 years, with northern hemisphere lakes melting an average of 45 days earlier than they did a century ago.

Lake ice plays many ecological roles: maintaining water quality, supporting biodiversity, retaining carbon and preventing water loss through evaporation. Rising temperatures threaten all of these, according to a review of research by Stephanie Hampton at the Carnegie Institution for Science in Washington DC and her colleagues. But scientists still don't know how this will ultimately affect freshwater systems.

Both the duration of freezing and the thickness of ice on lakes is decreasing – and these trends will only worsen in the coming years. If global air temperatures rise by between 1.5°C and 3°C (between 2.7°F and 5.4°F), there will be 13 to 24 fewer days of solid ice cover on northern hemisphere lakes, and ice-covered days at lower latitudes could decrease by 80 per cent. By 2080, 18 per cent of the world's 1.4 million lakes that formerly froze throughout the winter will only be intermittently covered in ice (*Science*, doi.org/g8d426).

Hampton and her team found that around 1.1 billion people live around lakes that freeze, and winter ice is important for many local economies. In Sweden, ice fishing generates $880 million annually. And seasonal roads that cross frozen freshwater bodies can be a vital lifeline. In February, four First Nations in Manitoba, Canada, declared a state of emergency when insufficient lake and river ice cut off the delivery of supplies.

18%

The proportion of lakes that froze all winter that won't by 2080

"This review is the most comprehensive to date on both the ecological and societal consequences of lake ice loss," says Isabella Oleksy at the University of Colorado Boulder. "While there are many scientific unknowns, the societal consequences are already here." ▮

Ice breaking up on Lake Michigan near Chicago, Illinois

MAKSIM ZABAROVSKII/ALAMY

Technology

Wikipedia awash with AI-written content

Chris Stokel-Walker

ARTIFICIAL intelligence may have contributed to just under 1 in 20 of the pages that have recently been published in English on Wikipedia. Some researchers are concerned that having AI-written content could reduce the site's reliability.

The roll-out of AI systems known as large language models prompted Creston Brooks at Princeton University and his colleagues to wonder about their implications for sources of information.

To investigate, they first ran the AI detection tools Binoculars and GPTZero on more than 14,000 Wikipedia pages published in English, French, German or Italian before March 2022, eight months prior to ChatGPT's release.

The tools flagged fewer than 1 per cent of these pages as having AI-written content. The true figure is probably nearer to 0 per cent, seeing as ChatGPT hadn't yet been rolled out, says Brooks. "It's definitely the case that any individual tool will have some false positives."

Next, they were used on nearly 13,000 Wikipedia pages created in August 2024, which suggested that 4.36 per cent of those published in English contained AI-written content (arXiv, doi.org/nqbd). The rates were generally lower for French, German and Italian-language pages.

"To me, it isn't that surprising, given it's happening pretty much all over society," says team member Denis Peskoff, also at Princeton University. "Wikipedia is particularly important [as a source of knowledge] just because it's being used in every single large language model as training data."

The researchers didn't identify individual pages that they believed had AI-generated content, but Brooks says a number of cases of its use were by small business owners who created pages about themselves and their companies.

They also believe that the owner of a manor house in England who was looking to sell their property made a Wikipedia page to amplify its importance.

Peskoff says the use of AI on Wikipedia could be problematic if unchecked, primarily due to its unreliability. "This is something that can scale up very, very quickly," he says. "Right now, it's 5 per cent, but you don't know where it'll be in two years."

Catherine Flick at Staffordshire University in the UK says that the tools the researchers used aren't infallible, but they are the best we have for detecting this sort of content.

Wikipedia, which is monitored by editors, will probably get better at removing AI-generated content, she says.

"I suspect that Wikipedia will become one of the few bastions of human-generated information, unlike other semi-moderated spaces that are rapidly filling up with AI-generated information," she says. "The particular culture of Wikipedia's editor-moderators is well suited to put up a battle against generative AI content, and I salute them for it."

A spokesperson for the Wikimedia Foundation, which owns Wikipedia, says that the study has some limitations, such as the fact that the tools used weren't trained to detect AI-generated content on Wikipedia specifically, and that AI policies vary on Wikipedia sites around the world. ▮

Art

Michelangelo's *The Flood* seems to depict a woman with breast cancer

James Urquhart

RENAISSANCE artist Michelangelo appears to have painted a woman with breast cancer in his fresco *The Flood* on the ceiling of the Sistine Chapel, which may have been a message about the inevitability of death.

Researchers have previously identified signs of breast cancer – including swelling and skin retraction – in his sculpture *Night*, dated to around 1526 to 1533.

Now, Raffaella Bianucci at the University of Paris-Saclay in France and her colleagues have spotted similar presentations in *The Flood*, which Michelangelo painted on the ceiling of the Sistine Chapel in Vatican City between 1508 and 1512. One of nine scenes from the Book of Genesis, *The Flood* portrays Noah's Ark, a story about God flooding Earth as punishment for humanity's immorality.

Bianucci and her team noticed one woman whose right breast has a retracted nipple and areola, surrounded by indentations and

ALBUM/ALAMY

The woman (bottom left) has signs of breast cancer, such as lumps

lumps (*The Breast*, doi.org/nqbf). They also noted a slight bulge near her armpit, which could represent enlarged lymph nodes, another indication of cancer.

Michelangelo participated in human dissections before painting *The Flood* and therefore probably had some knowledge of cancerous tumours, which have been recorded since antiquity, says Bianucci.

Michelangelo may have painted breast cancer to represent illness as a punishment for lust, because this "sin" was associated with female breasts, says Bianucci. A theme of Genesis is that God made humanity aware of mortality as a punishment for sin.

"It's reasonable to presume that the message is to do with the inevitability of death," says Agnes Arnold-Forster, a medical historian at the University of Edinburgh in the UK. "Cancer was known to be incurable, levying an acute emotional toll, and it's likely that a woman who found a lump in her breast would know the potential outcome."

"It's likely that a woman who found a lump in her breast would know the potential outcome"

However, Michelangelo may not have deliberately depicted cancer, because there are no ulcerations on the woman's skin, says Arnold-Forster. "This would have been a more obvious visual sign of the disease if Michelangelo had intended to depict it. It could, of course, be cancer – we just can't know with certainty." ▮

Health

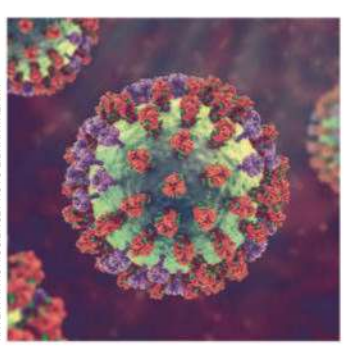
Flu viruses evolved proteins to cut through mucus

BEFORE viruses can infect cells, they must often traverse layers of the body's protective mucus. Understanding how evolution optimised the influenza A virus for this slimy task could help us create new antiviral drugs.

If you just dropped an influenza A virus into mucus, natural diffusion would never carry it to cells fast enough to cause an infection, says Siddhansh Agarwal at the University of California, Berkeley. Influenza A viruses get around this problem with specially evolved proteins on their surface.

Mucus molecules are covered in complex sugars called sialic acid, and influenza A's outer proteins either stick to or sever them. This lets the virus propel itself forwards while leaving severed acids in its trail.

The researchers assessed how good influenza A is at this leap-frog motion. They simulated the process, tweaking the various factors that could influence the virus's movement, including the arrangement of the two types of proteins, how often and how strongly each binds to the sugars, and the friction between the virus and the mucus. That revealed a "Goldilocks zone" in which every factor was just right for influenza A to move as quickly through the mucus as physics allows (*Physical Review Letters*, in press).



KATERYNA KON/SCIENCE PHOTO LIBRARY/ALAMY

Proteins dotted on influenza A viruses help breach our bodies' mucus barriers

"The virus has a lot of tasks to do to be successful," says team member Boris Veytsman at George Mason University in Virginia. "What we seem to find is that going through the mucus is one of the important ones."

The discovery implies that the way viruses move through mucus, which differs between animal species, may be important for how they jump between animals and even cause pandemics, says Bortolo Mognetti at the Free University of Brussels in Belgium. But more details must be added to the simulations, he says, including situations where the virus makes twists and turns, instead of moving in a line. ▮

Karmela Padavic-Callaghan

Physics

Meet the mass-shifting particles

Bizarre particles discovered that only have mass when moving in one direction

Karmela Padavic-Callaghan

STRANGE particles that have mass when moving one direction but no mass when moving in another were first predicted more than a decade ago. Now, they have been glimpsed in a metallic compound exposed to extreme conditions.

"This [particle] is very bizarre. You can imagine walking on the streets of New York and if you go straight, you are super light, you are massless. But turn 90 degrees east or west, and you become super massive," says Yinming Shao at Pennsylvania State University. He and his colleagues came across these so-called semi-Dirac fermions while studying how metals behave when exposed to high magnetic fields.

They focused on a compound of zirconium, silicon and sulphur – a shiny compound that conducts electricity like any other metal, but with properties that become unusual in extreme conditions. The researchers cooled a chunk of it down to only a few degrees above absolute zero, and then exposed it to a magnetic field more than ten million times stronger than Earth's.

This field forced the electrons in it to behave bizarrely. Instead of moving forwards in a kind of river of electric current, they traced out circular trajectories, like eddies in that river. As they were so cold, they were also susceptible to quantum effects, meaning each acted like a wave that self-reinforced as it flowed around the eddy. These behaviours caused the semi-Dirac fermions to emerge.

The researchers shined infrared light onto the material and analysed the way it reflected back. This revealed how the particles inside the metallic compound responded to being hit by light. They varied the magnetic field strengths and frequencies of light to identify the fingerprint of a semi-Dirac fermion.

When electrons get sent into a spin, truly weird particles arise

LAGUNA DESIGN/SCIENCE PHOTO LIBRARY

Shao says this phenomenon had been predicted 16 years ago for materials like graphene, but he and his team had to develop a mathematical model for this compound metal to confirm they were matching the fingerprint to the right exotic particle. When the magnetic field pointed in the same direction as the moving particles, it was as if they had no mass at all. But when the magnetic field was at a right angle to the particles' trajectories, they had mass (*Physical Review X*, in press).

"It is exciting that experimentalists were able to realise those quasiparticles in a real quantum material," says Bruno Uchoa at the University of Oklahoma. He says semi-Dirac fermions are an exotic hybrid of regular electrons that exist in any metal and more unusual cosmic particles like massless neutrinos. As such, they stand a chance of revealing many new physical behaviours, he says. For instance, they may be able to form a viscous fluid inside the metal, which would be rather different than conventional electronic currents.

But Shao says we must answer many open questions regarding what semi-Dirac fermions can do before they can be put to practical use. "For this material, there's still many mysteries to further explore," he says. ▮

Physics

Cloud-inspired material bends light around corners

SCIENTISTS have discovered a light-bending technique inspired by the way clouds scatter sunlight.

Daniele Faccio at the University of Glasgow, UK, and his colleagues say they are shocked this type of light scattering wasn't noticed before. It works on the same basis as clouds, snow and other white materials that absorb light: once photons hit the surface of such a material, they are scattered in all directions, barely penetrating at all and getting reflected out the way they came.

"The light bounces around and sort of tries to get in, and it's bouncing off all the molecules and the defects," says Faccio. "And eventually what happens is it just gets reflected back because it can't get in."

To replicate this, the team 3D printed objects from opaque white material with thin tunnels of clear resin within. When light is shone at the material, it travels into these tunnels and is scattered – just as light is on snow or clouds. However, instead of scattering randomly in every direction until they are evenly dispersed, the photons are directed to return to the resin tunnel by the opaque material. The team put this to use, creating a range of objects that steer light in an organised way (*Nature Physics*, doi.org/nqbb).

The researchers say their material boosts light transmission by more than two orders of magnitude compared with solid blocks without the same clear tunnels, and also allows it to be directed around curves. It is much less efficient than fibre optic cables, which use reflection to route light long distances, but it is also very simple and cheap. The light-bending method could also make use of existing tunnels of translucent material, such as tendons and fluid in the spinal column, to provide new ways to carry out medical imaging.

"The light-bending method could also make use of translucent material like tendons and spinal fluid"

Faccio says the same principle also works to direct heat and neutrons, and could therefore also find use in applications like cooling systems and nuclear reactors. ▮

Matthew Sparkes

Technology

How driverless cars can predict unseen objects' movements

Jeremy Hsu

AN ALGORITHM could help driverless cars predict the sudden appearance of hidden vehicles, cyclists and pedestrians.

"We ensured that it captured real-world complexities like hidden [objects] moving unpredictably," says Hari Thiruvengada at VERSES AI, a cognitive computing company headquartered in California.

Hidden obstacles are difficult for autonomous vehicles to detect because their AI systems often struggle when presented with unexpected situations. To address this, Thiruvengada and his colleagues developed a new algorithm with Swedish automaker Volvo Cars, training and testing it in a simulation based on data from Waymo driverless cars (arXiv, doi.org/np7m).

The model computes the probability that a bike or some pedestrians could be hidden behind, say, a parked truck, then predicts the possible trajectories of each. It works by reducing such complex and rapidly changing situations to a simpler set of possible motions that the potential hidden objects might take.

Once the car's sensors have confirmed whether those people or objects exist, it can update its speed, direction and behaviour, helping it make faster and more accurate decisions – even during situations it wasn't trained to handle. ▮

Waymo self-driving cars collect data on the motion of surrounding objects

BOUTEFEU/ALAMY

Archaeology

Skeleton in Roman grave has bones from eight people

Christa Lesté-Lasserre

A COMPLETE skeleton found in a Gallo-Roman grave in western Belgium is not a Roman individual after all, but rather a bizarre mix of people spanning thousands of years.

Laid to rest on the right side with tucked-up legs, the remains feature long bones from seven unrelated men and women who lived just over 4000 years ago – of varying ages and separated by several centuries – and the skull of a Roman woman who died 2500 years later.

The assembled skeleton reflects true craftsmanship and knowledge of anatomy, but the question of who assembled it – and why – remains a mystery, says Barbara Veselka at the Free University of Brussels in Belgium.

"This really gives more insight into the kinds of social and cultural aspects of life and death in both these time periods," she says. "It's like, Romans cremated their dead and put them in the ground and that's it? Well, evidently not. They might have done way more than we thought."

In the 1970s, researchers found the full skeleton in a 2nd-century Roman cremation cemetery in Pommeroeul, Belgium. A Roman bone pin placed near the head led scientists to believe this was a Roman burial, and the skeleton was presented as such at the Musée du Malgré-Tout in Viroinval, Belgium.

More recently, however, Veselka and her colleagues had doubts. The skeleton's side-lying position was typical of Early Bronze Age burials, in contrast to Roman burials with people laid flat on their backs. And despite being perfectly aligned,

PAUMEN, WARGNIES, AND DEMORY; FÉDÉRATION WALLONIE-BRUXELLES

This skeleton (left) was discovered in a Gallo-Roman grave – but only the skull (above) dates from the Roman period

the vertebrae looked like a mix of adolescent and senior bones, and the femur looked too big for the pelvis. "I started thinking, OK, something really weird is going on," she says.

So the team ran radiocarbon dating on the arm and leg bones, the skull and five toes. They also ran ancient DNA analysis on several long bones and the skull. To their surprise,

> **"Human bodies are conceptualised and charged with cultural meanings across time"**

their results pointed to at least seven unrelated individuals spanning several generations 4212 to 4445 years ago.

Radiocarbon dating on the skull was inconclusive, but DNA analyses revealed it belonged to a Gallo-Roman woman whose genes closely matched those of two young siblings that were buried in another Roman cemetery, 150 kilometres to the east, about 1800 years ago (*Antiquity*, DOI: 10.15184/aqy.2024.158).

Archaeologists know ancient people would occasionally manipulate human bones, reassembling them into a single skeleton, and even crafting tools from them and possibly consuming their marrow.

However, this is the first discovery of a skeleton with such a wide mix of ages and cultures, says Veselka. It was particularly convincing as a single individual, reflecting the builders' knowledge of human anatomy, she says. "They knew what they were doing, for sure."

Bronze Age tribes might have collected older bones to create a single skeleton as a symbol of unity, she suggests, and the Romans might have added a skull out of respect for the dead if they accidentally broke the original while digging graves. An alternative theory is that – for yet unknown reasons – the Romans built the entire construction.

What exactly happened in this Gallo-Roman grave remains a "fascinating puzzle", says Marco Milella at the University of Bern in Switzerland. The fact that the body was reconstructed, probably twice across thousands of years, offers evidence of how human bodies are "continuously conceptualised and charged with cultural and social meanings" across time, he says. ▮

Health

War-era sugar limits show health benefits of cutting down in early life

Carissa Wong

SUGAR rationing during and after the second world war seems to have improved the health of people conceived in the UK at the time, cutting their risk of developing type 2 diabetes and high blood pressure decades later.

Exposure to a high-sugar diet in the uterus has previously been linked to a raised risk of obesity, which is known to increase the risk of type 2 diabetes and high blood pressure, or hypertension. Whether this is a causal link is unclear, however, and investigations into such questions are hampered by it being hard, or even unethical, for researchers to force people to follow specific diets.

But the same isn't true of wartime governments, which is why Tadeja Gracner at the University of Southern California and her colleagues made use of a situation in the second world war that acted like a natural experiment. In January 1940, a few months into the war, the UK began rationing food. This included limiting adults to around 40 grams of sugar per day. When rationing ended in September 1953, people rapidly increased their sugar consumption to roughly twice as much.

Gracner's team analysed the health records of more than 38,000 people who were surveyed as part of the UK Biobank project between 2006 and 2019. All were aged between 51 and 66 at the time of the surveys and conceived during the last few years of rationing, meaning they were exposed to limited sugar intake in the uterus and early life. The researchers also looked at the same data from 22,000 people conceived a year or so after rationing ended. The groups had a similar composition in terms of sex and race, and had a similar family history of type 2 diabetes, to enable comparisons between them.

GADO IMAGES/ALAMY

People in the UK lining up for sugar rations in 1942

Across both groups, there were more than 3900 people diagnosed with type 2 diabetes, and 19,600 with hypertension, but the prevalence of both conditions was much lower for those who were conceived during rationing.

Members of this group had

35%

The drop in type 2 diabetes risk if conceived during rationing

a 35 per cent lower chance of developing type 2 diabetes by their mid-60s, and those who did develop the condition did so on average four years later than those conceived after rationing ended. For hypertension, those in the group conceived during rationing were 20 per cent less likely to have the condition by their mid-60s, and again saw an average delay in developing it, this time of two years (*Science*, doi.org/np8z).

Crucially, while rationing saw many changes in the diets of people in the UK, it appears that cutting down on sugar made a big difference. Despite the changes in what food was available, average diets during rationing contained similar levels of other food types, such as fats, meat, dairy, cereal and fruit, as afterwards.

One explanation might be that increased early exposure to sugar sets up a preference for eating sweet things throughout life, says Gracner. It could also lead to epigenetic changes that reduce how well people control blood sugar levels, raising the risk of type 2 diabetes and hypertension, she says.

In any case, while the UK's dietary guidelines for sugar intake today are similar to the amount eaten during rationing, actual consumption is higher. The results show there are clear benefits in cutting down, says Scott Montgomery at Örebro University in Sweden. "People should be reducing sugar intake to the recommended levels." ▮

Technology

Radar lets spies listen in on phone calls from afar

Matthew Sparkes

SPIES can eavesdrop on conversations by using radar to detect tiny vibrations in smartphones and employing artificial intelligence to accurately transcribe them. The trick even works in noisy rooms, as the radar homes in on the phone's movement and is entirely unaffected by background hubbub.

Millimetre wave sensing is a form of radar that can measure movements of less than 1 mm by transmitting pulses of electromagnetic wave energy and detecting the reflected beams.

Suryoday Basak at Pennsylvania State University and his colleagues used a commercially available sensor to pick up the tiny vibrations in the earpiece speaker of a Samsung Galaxy S20 as it played audio clips. They then converted the signal to audio and passed it through an AI speech recognition model, which transcribed the speech (arXiv, doi.org/np66).

Although the radar signal is unaffected by other noises in the room, Basak says extracting the smartphone's vibration from extraneous movements produced by the person holding it is still like finding a needle in a haystack. The user's breathing causes vibrations of a few millimetres and their heartbeat creates vibrations an order of magnitude smaller. But the movement of the earpiece speaker from the conversation itself is another two orders of magnitude smaller: typically just 7 micrometres.

"It's very difficult. That's the caveat. There are very weak vibrations, but there are certain conditions in which you can tease them out," says Basak

By using an AI model to transcribe the sound, they were able to achieve a word accuracy rate of 50 per cent and a character accuracy rate of 67 per cent from a range of up to 125 centimetres. ▮

Environment

China's carbon emissions may have peaked due to its clean energy rollout

Madeleine Cuff

THE adoption of wind and solar power across China may have caused the country's emissions to peak in 2023, in what would be a historic turning point in the fight against climate change.

China's CO_2 emissions hit an all-time high in 2023 as its economy rebounded from the impacts of the covid-19 pandemic. Since then, huge amounts of wind and solar power have been added to the nation's electricity grid.

A new analysis indicates that China's carbon emissions were flat from July to September 2024 after falling 1 per cent in the second quarter of the year. This means 2024 emissions may remain flat on 2023 levels overall, or even fall.

"China's emissions growth has been the dominant factor pushing global emissions up for the past eight years since the signing of the Paris climate agreement," says Lauri Myllyvirta at the Centre for Research on Energy and Clean Air, a think tank in Finland, who carried out the analysis using official figures and commercial data for the website Carbon Brief.

In its climate change plan submitted to the United Nations, China promised to peak its greenhouse gas emissions before 2030, and to reach net zero by 2060. But experts warn this isn't ambitious enough given China's impact on global climate change as the world's largest emitter. Peaking emissions as early as possible is crucial, says Myllyvirta.

China is racing to ramp up electricity supply and meet increasing demand for power. This jumped by 7.2 per cent between July and September compared with a year earlier, driven by rising living standards and heatwaves increasing demand for cooling.

New renewables capacity has been deployed across China at breakneck speed to help bridge the power demand gap. Based on current trajectories, the growth in solar power in China this year will equal the total annual power generation of Australia in 2023.

However, coal-fired power use rose by 2 per cent, and gas generation by 13 per cent, during July to September in response to rising demand. This led to an overall rise in CO_2 emissions from the Chinese power sector of 3 per cent, although it was offset by a slowdown in construction across China, as investment in real estate contracted.

Demand for oil fell by 2 per cent in the third quarter of the year, due to the increasing adoption of electric vehicles. "The rapid clean energy growth, if maintained, paves the way for a sustained emissions decline," says Myllyvirta.

But he warns that a plateau or drop in emissions in 2024 isn't guaranteed, as measures to revive the economy could push them up. Carbon emissions must fall by at least 2 per cent in the final three months of the year to dip below 2023 levels, he says.

Yet signals from the Chinese government suggest it expects emissions to keep rising in the country to the end of the decade, which would blow through the remaining global carbon budget for 1.5°C. ▮

COSTFOTO/NURPHOTO VIA GETTY IMAGES

A solar power plant in Taizhou, Jiangsu province, China

Mathematics

Chimps typing Shakespeare? Don't hold your breath

IF EVERY chimpanzee on Earth were given a typewriter, they wouldn't reproduce the works of William Shakespeare even if they kept on typing until the heat death of the universe, researchers have calculated.

The so-called infinite monkey theorem states that if you had an infinite number of primates, or one primate had infinite time, they would almost certainly type out any given text an infinite number of times. The origins of the theorem are obscure, but it is commonly attributed to mathematician Émile Borel or biologist Thomas Henry Huxley.

Stephen Woodcock at the University of Technology Sydney (UTS) in Australia says that while the theorem is mathematically true, it is "totally misleading".

He and his colleague Jay Falletta, also at UTS, have now mathematically tested a more realistic proposition, which they call the finite monkey theorem. In their scenario, the current global population of around 200,000 chimpanzees would type one key every second until the end of the universe in about 10^{100} years (a 1 followed by 100 zeros).

They estimate that it would take a single chimp 300,000,000 random keystrokes to write the word "bananas", and the probability that one of those 200,000 apes would actually achieve the modest feat in its lifetime would be just 5 per cent.

"If every atom in the universe was a universe in itself, it still wouldn't happen"

However, the chances rapidly become infinitesimal as the task becomes more complicated – so the probability of a single chimp writing "I chimp therefore I am" is just 1 in 10 million billion billion.

The entire works of Shakespeare, comprising nearly 885,000 words, would take $10^{7448366}$ random keystrokes, requiring much more time than the expected lifespan of the universe.

"If every atom in the universe was a universe in itself, it still wouldn't happen," says Woodcock. ▮

James Woodford

Health

Mapping the world of cancer

Extensive study of the cells and regions in cancerous tumours has revealed new insights into how they grow and evolve over time, reports **Grace Wade**

WE NOW have some of the most detailed maps ever made of several cancers, along with new tools and methods for analysing them. The findings come from an initiative called the Human Tumor Atlas Network, and provide clues about how cancers form, evolve and become resistant to treatment.

Cancer develops when genetic mutations spur cells to grow and proliferate uncontrollably. Much of what we know about it comes from genetically analysing tumours. Until recently, we could only do this by combining and analysing all the genetic data in a tumour sample at once, making it impossible to identify individual cell types.

But tumours aren't monolithic. "They're complex, like ecosystems that consist of not just tumour cells, but also immune cells, endothelial cells and other support cells," says Daniel Abravanel at the Dana-Farber Cancer Institute in Boston. He led one of several teams that contributed to the cancer mapping project (*Nature*, bit.ly/40wFM77).

Tumour maps

Thanks to the advent of more sophisticated tools, the teams working on the project have now been able to identify individual cells or determine their functions in tumours from nearly 2000 people with 20 different kinds of cancer.

As part of the initiative, Li Ding at Washington University in St. Louis, Missouri, and her colleagues mapped 131 tumour regions from 78 people with cancer types that show up in the breasts, colon, pancreas, kidneys, uterus and the bile ducts that connect the liver and gall bladder to the small intestine. They used

PHANIE – SIPA PRESS/ALAMY

3D modelling of a kidney (with tumour in purple) helps guide surgeons

a technique called single-cell sequencing to measure which genes were turned on or off in each cell of a tumour sample.

The researchers also viewed tissue samples under powerful microscopes to determine the location and structure of cells. Next, they built 3D models of tumours, showing how cells within them are organised and interact.

They found that, within tumours, cancer cells form distinct clusters known as microregions. They then grouped these areas based on similar genetic alterations, such as high or low immune cell activity. Evolution within the genetic activity of cells in microregions appears to be a major factor in cancers becoming resistant to treatments.

Further research from the Human Tumor Atlas Network suggests that multiple cells can sometimes coordinate to form colon cancer. "For decades, the consensus in the field has been that a tumour originates from a single cell," says Doug Winton at the University of Cambridge.

Winton and his colleagues used mice that were genetically engineered so their cells changed colour when they became cancerous. This made it possible to identify and track tumours as they formed in the guts of the animals. The researchers found that about 40 per cent of colon tumours originated from multiple cells, which cooperated to outcompete neighbouring cells.

A separate group of researchers led by Ken Lau at Vanderbilt University in Tennessee also

"Tumours are complex, like ecosystems that consist of immune cells and other support cells"

identified biomarkers for monitoring tumour evolution. Naturally occurring mutations create permanent genetic changes in tissue, which allowed the researchers to reconstruct the sequence of events, creating a molecular timeline of each tumour's growth.

Using this approach, they analysed early precursors of colon cancer in mice and people and found that up to 30 per cent had a multicellular origin.

Early detection

The best predictor we currently have for determining whether a precancerous lesion in the colon will become cancerous is its size, says Lau. Understanding how colon cancer forms can improve our ability to screen precancerous lesions and detect cancer earlier, he says.

As part of the initiative, researchers led by Ben Raphael at Princeton University created an algorithm that quantifies the proportion of cancerous and non-cancerous cells in a tumour and investigates how these cells interact, which can also help discern how a tumour is growing.

The cancer mapping project uncovered some surprises. Abravanel and his colleagues collected 67 tumour biopsies from 60 people with metastatic breast cancer, meaning it had spread to other organs, such as the liver, brain and lungs. They found that samples collected from the same participant at different time points were genetically very similar. "You would expect to see different mutations evolve over time," says Abravanel.

Together, these discoveries bring us closer to understanding how cancer forms and evolves, which, in turn, could improve treatment.

Abravanel says this could help in his clinical practice as well: "We try as best we can to match the right treatment to the right patient, but largely we aren't able to, for individual cases, pull out what the best therapy would be at that moment in time." ▮

Physics

Extremely long-lived 'Schrödinger's cat' shatters quantum record

Karmela Padavic-Callaghan

QUANTUM superpositions are typically fragile and fleeting, but one such state has now been maintained for a record-breaking 23 minutes.

This long-lived phenomenon is known as a cat state, named for Erwin Schrödinger's famous thought experiment where a cat is placed in a box under such peculiar circumstances that it becomes impossible to tell whether it is living or dead. Cat states are superpositions where a quantum object can be in several mutually exclusive states, but it is impossible to tell which one it actually occupies – it effectively simultaneously occupies them all.

Researchers have for years created cat states with particles of light and even tiny crystals, but these states always quickly collapsed into a single, well-determined one. Now, Zheng-Tian Lu at the University of Science and Technology of China and his colleagues have trapped atoms with light to sustain a cat state for an exceptionally long time.

They cooled about 10,000 ytterbium atoms down to a few thousandths of a degree above absolute zero, trapping them with the electromagnetic forces of laser light. Under these conditions, the atoms' quantum states could be very precisely controlled – the researchers put each atom into a superposition of two states that had two very different spins.

1400
seconds is the longest a quantum cat state has been kept stable

Typically, disturbances from the environment would collapse the atoms into a single spin state in a matter of seconds or milliseconds, but the team tuned their lasers to make the cat states last an unprecedented 1400 seconds – or the length of the average sitcom episode (arXiv, doi.org/np4t).

"It's a big deal because they're making this beautiful cat state in an atomic system and it's stable," says Barry Sanders at the University of Calgary in Canada.

Such a state is very sensitive to everything that happens in its environment, so it could be used to detect and study subtle magnetic forces or to probe new and exotic effects in fundamental physics, he says. "A probe gets jiggled and pushed and nudged and prodded, and then by seeing what happens, you learn about the things that interact with it."

The researchers showed that the cat state's sensitivity for measuring magnetic fields is already very close to the fundamental sensitivity limits set forth by the laws of quantum mechanics. Because it lasts so long, the cat state would not only be a sensitive probe but also one that can keep collecting data past a single snapshot, possibly capturing effects that happen both very quickly and more slowly, says Sanders.

MODERN PARLANCE PHOTOS/ALAMY

The unknowable aliveness of Schrödinger's cat is key to more stable quantum devices

Cat states may become useful for quantum information processing where they could be used as a very stable memory that could store extra information. This could be used in a device like a quantum computer to course-correct whenever it makes an error. ▮

Palaeontology

Oldest known tadpole fossil is 161 million years old

AN EXQUISITELY preserved fossilised tadpole is the oldest ever discovered by science, dating back 161 million years – and its anatomy is strikingly similar to some of today's species.

Palaeontologists found the fossil in January 2020 while searching for feathered dinosaurs in Santa Cruz province in Argentina.

"They did not achieve their goal," says Mariana Chuliver at Maimonides University in Buenos Aires, Argentina. "However, one team member found a stone with a particular imprint on it – a fossil tadpole."

Chuliver and her colleagues have now identified the tadpole as belonging to the extinct frog species *Notobatrachus degiustoi*, deciphered from the hundreds of adult specimens that have been found in the same fossil deposit since 1957.

Until now, scientists had never unearthed a tadpole fossil from before the Cretaceous Period, which began about 145 million years ago.

The fossil was so well preserved that eyes and nerves are visible in its head, as well as a forelimb and part of its tail (*Nature*, doi.org/np5t). The team estimates it would have been around 16 centimetres long, comparable to the biggest tadpoles that exist today.

MARIANA CHULIVER ET AL., JOURNAL (2024)

The fossil was found in Santa Cruz province, Argentina, in 2020

The similarities between the ancient and modern tadpoles are so great that the team could identify the fossil's stage of development: it was just about to turn into a frog.

Earth's climate used to be warmer and wetter, which probably made it easier for tadpoles to reach a large size, combined with the fact that there was less competition and predation, says Chuliver.

Jodi Rowley at the Australian Museum in Sydney says the discovery of the oldest known tadpole "confirms how successful and stable the 'typical' frog life cycle is – the one we all learn about at school". ▮

James Woodford

Space

Asteroids could take us to Mars

Travelling inside space rocks would shield astronauts from harmful radiation

Jonathan O'Callaghan

ASTRONAUTS could travel to Mars and Venus by hitching a ride on asteroids, burying themselves under the surface to avoid damage from radiation.

High levels of harmful radiation from the sun and galactic cosmic rays would be a major concern for humans making long journeys beyond Earth's protective magnetic field.

"Going to Mars and coming back again is going to double or triple the amount of time people are exposed to radiation [compared with an International Space Station mission]," says Matthew Gill at Space Radiation Services in the UK. "We're not talking Chernobyl levels of radiation sickness, but there is going to be a higher probability of getting cancer in their lifetime."

One way to protect against this radiation is to build spacecraft with additional shielding. But Arsenii Kasianchuk and Volodymyr Reshetnyk at Taras Shevchenko National University of Kyiv in Ukraine have proposed an alternative: travelling inside an asteroid. "It is more cost-effective to use an alternative material that is already floating in space," says Kasianchuk.

The pair studied 35,000 known asteroids near Earth's orbit to see if any could be used for interplanetary missions between now and 2120. Specifically, they looked for asteroids that passed close enough to Earth and Mars or Venus that a spacecraft could easily land on and depart, and were also large enough to house a spacecraft.

"There's a whole world of things that are challenging about digging holes in the middle of asteroids"

That gave them a list of 120 asteroids, some of which fly past the planets regularly every two to three years, while others are less frequent, with only one pass in a century (arXiv, doi.org/np4c).

The idea is that astronauts would ride one asteroid to one destination, such as Earth to Mars, and then wait for another asteroid to pass in the other direction for their return journey. "The asteroids in this case are really like trains," says Kasianchuk. The journey times were up to 180 days for missions to Mars or Venus.

One asteroid will fly from Earth to Venus to Mars in 230 days in 2079 and another will come back in the other direction in 2080, providing an opportunity to visit both planets in one mission. Although Venus's orbit is closer to the sun than the two other planets, an asteroid can pass it in the middle when Earth and Mars are on opposite sides of the sun.

Colin Snodgrass at the University of Edinburgh in the UK says there are some practical challenges to the idea. For one thing, matching the speed of a passing asteroid to land on its surface would be very difficult. "They're talking about velocities of up to 30 kilometres a second," he says – about 67,000 miles per hour – requiring a "crazy amount of fuel".

Finding a way to bury into the surface of an asteroid would also be extremely difficult. "There's a whole world of things that are technologically challenging about digging holes in the middle of asteroids," says Snodgrass.

Kasianchuk says this could be done by firing an uncrewed device ahead of the rendezvous to excavate a cylindrical tunnel into the asteroid that a spacecraft could then fly into.

He hopes that more asteroids might be found in the coming years that could be used for such voyages. "More and more near-Earth asteroids are discovered every year," he says. "The number of candidates for interplanetary transfers will continue to grow." ▮

Health

Antibiotics change your gut microbiome for many years

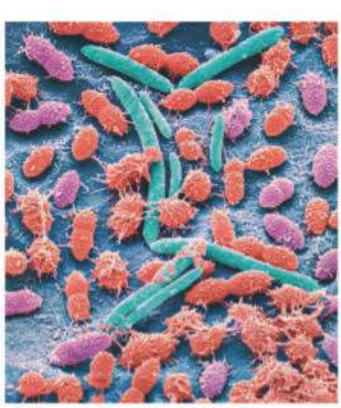
TAKING antibiotics can be life-saving, but a course lasting less than two weeks may also reduce the diversity of your gut microbiome for many years.

Gabriel Baldanzi at Uppsala University in Sweden and his colleagues analysed data from more than 5700 adults who took part in three studies in which stool samples were collected.

Based on their medical records, more than 1400 of the participants had taken a course of antibiotics, lasting less than two weeks, between four and eight years before they provided a stool sample. The remaining participants had taken no antibiotics in the eight years before providing a sample.

The researchers found that participants who had taken antibiotics called macrolides, which are commonly used to treat skin and lung infections, had 56 fewer bacterial species in their gut, on average, four to eight years later, compared with those who took no antibiotics (medRxiv, doi.org/np3x).

Those who took antibiotics called cephalosporins – which are used against urinary tract infections and meningitis – had 43 fewer bacterial species in their gut, on average, up to eight years later. The same was true for those who took a course of the antibiotic clindamycin, which treats certain skin infections. The team accounted for differences that could affect the results, such as age and sex.



STEVE GSCHMEISSNER/SPL/ALAMY

Scanning electron micrograph of bacteria from a sample of human faeces

Researchers already knew that antibiotics can lower the diversity of bacterial species in the gut for up to two years, but this work makes it clear that this effect can be even longer lasting.

Most people have at least several hundred bacterial species in their gut. Losing around 50 species may make them more vulnerable to infections, such as *Clostridium difficile*, says Ines Moura at the University of Leeds in the UK. If the balance of microorganisms in the gut becomes disrupted after someone takes antibiotics, this bacterium can dominate, which can lead to diarrhoea. ▮

Carissa Wong

Physics

Quantum batteries output more energy than they store

Karmela Padavic-Callaghan

IF LINKED in the right way to the device they are powering, quantum batteries could give off more charge than they hold.

The amount of useful work that can be gained from a quantum energy-storage device is called ergotropy. While traditional batteries can give off almost all of their charge, quantum batteries don't always manage to pass on all of their ergotropy. But use a quantum process to make the behaviour of the battery and the device being powered inseparable, say by entangling them, and it is as if you can get a AAA battery to produce the power of a larger AA battery.

Karen Hovhannisyan at the University of Potsdam in Germany and his colleagues modelled the quantum charging process, with the battery and device as a pair of quantum bits. They compared how much ergotropy was exchanged under two scenarios: one where all pairs of device-and-battery quantum states were inseparable, or correlated, and one where the two could always be treated as independent.

Team member Rick Simon at the University of Exeter, UK, says it was challenging to rigorously prove that without correlations, some of the ergotropy is always lost during the transfer, but they ultimately determined that correlations are an invaluable resource for quantum batteries and let them give off more charge than they hold. The research will be published in *Physical Review Letters*.

This type of analysis can show when quantum batteries may be useful in practice, says Pharnam Bakhshinezhad at the Vienna University of Technology in Austria. It is useful to know what kind of correlations could make the process more efficient, as well as how much energy it would take to put those in place, he says. ▮

Environment

The Amazon is teetering on the edge of a tipping point

Luke Taylor

MICHAEL DANTAS/AFP VIA GETTY IMAGES

Fires have released carbon dioxide from the Amazon

DEFORESTATION has pushed the Amazon to the very edge of a tipping point that would see it become a net source of carbon dioxide and accelerate climate change, according to a report using new technologies to map carbon emissions in the rainforest from 2013 to 2022.

Although it is historically a carbon sink, the Amazon biome released more carbon than it absorbed during 2015-16 and 2017-18, the report by Planet Labs, a company that provides satellite imaging, and the non-profit organisation Amazon Conservation found.

"The Amazon is teetering between sink and source. But at some point, with continued degradation, it could flip entirely to a permanent carbon source," says Matt Finer at Amazon Conservation, who led the research.

The 6.7 million square kilometres of trees, plants and soil in the Amazon take in carbon as the rainforest grows, cooling the planet, but researchers are concerned that deforestation is reducing the rainforest's capacity to regulate the global climate.

The south-eastern Amazon, which has seen the most deforestation, has already become a steady net emitter of carbon as its ecosystem has been transformed.

Finer and his colleagues used machine learning, satellite imagery, airborne lasers and global biomass data from NASA to map the changes in the entire rainforest canopy at a resolution of 30 metres, an unprecedented level of detail. They then used the biomass data to compare the carbon lost from fires and forest clearing against the carbon stored from forest growth.

0.1%

Amount of carbon gained by the Amazon from 2013 to 2022

A previous report by Amazon Conservation found that the Amazon absorbed 64.7 million tonnes of carbon between 2013 and 2022 – a gain of just 0.1 per cent of the 56.8 gigatonnes of carbon stored in the rainforest. Brazil, Colombia, Suriname, Guyana and French Guiana took in the largest amount of carbon, while Bolivia, Venezuela, Peru and Ecuador released the largest amount.

The new breakdown of that data into two-year periods shows how the forest swung from carbon sink to source during periods that coincided with severe seasons of drought in 2015 and 2016 and fires in 2016 and 2017.

Above-ground carbon storage rebounded from 2019 to 2022. The study doesn't include more recent data, but fires and droughts in 2023 and 2024 suggest the Amazon has returned to being a carbon source, says Finer.

"In the 1990s, the Amazon forest was removing close to 1.5 billion tonnes of carbon dioxide a year, but as this study shows, when you add together emissions from deforestation, degradation and fires, the forest's ability to remove carbon is now very small," says Carlos Nobre at the University of São Paulo, Brazil.

Although the Amazon's shrinking capacity to take in carbon is concerning, it is important to note that the area studied in the report is the entire Amazon biome, which includes Manaus, a city of 2 million people, says Erika Berenguer at the University of Oxford. "People usually assume that when we are talking about 'the Amazon' that we are only talking about the forest," she says. "If we were to isolate just the forest, it is a sink." ▮

‘Bel Can-do’

In November 2022 we introduced the Bel Canto. Instantly making haute horology accessible. This subtly chiming timepiece caused a cacophony. And enormous demand. (The first 600 sold out in 8 hours.) Asked could we produce 5,000 annually, our Swiss CEO Jorg Bader Snr replied: “No. But we’ll find a way.” Because that is our way. Today, our supply chain is as fit for purpose as the gear chain of the new Bel Canto Classic. Which features a dressed-up dial. A dialled-down handset. And a gorgeous guilloché finish, with a precision only achievable (and affordable) using a femto laser. Outward displays, we like to think, of inward grace.

(Bel Can-)Do your research

Christopher Ward

christopherward.com

Views

The columnist
Rowan Hooper on a future where seaweed saves us from CO_2 p22

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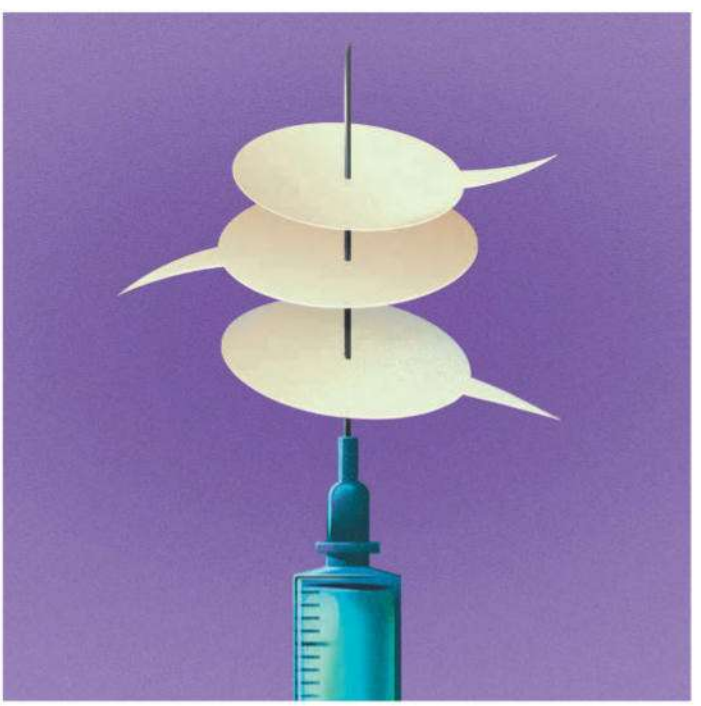
Culture columnist
Simon Ings enjoys a satire of world leaders tackling a crisis p30

Comment

Taking a shot

We are living in a vaccine hesitant-moment, with conspiracy theories thriving on social media. We need to push back, says **Simon Williams**



ADRIÀ VOLTÀ

IN May 2014, in El Carmen de Bolívar in northern Colombia, mainstream news and social media were awash with reports and viral videos of adolescent girls experiencing symptoms of a "mystery illness", including fainting and numbness. Claims were made that this was linked to side effects from the human papilloma virus (HPV) vaccine.

Although Colombian health authorities' investigations found no evidence of a biological link between the vaccine and the symptoms reported, the effects of these claims, which had been spread via social media, lingered. By 2016, Colombia's female HPV vaccination rate, in 2012 one of the world's highest, had plummeted to only 2 per cent, according to World Health Organization estimates. It has taken until 2023 for rates to start to recover, although they remain significantly lower (at 11 per cent in 2022 and 52 per cent in 2023) than the high of 87 per cent in 2012.

Vaccine misinformation casts a long shadow. More than 25 years after Andrew Wakefield's infamous *Lancet* publication, myths surrounding MMR vaccines and autism are still causing parents around the world to refuse the vaccine for their kids, contributing to rising measles cases. A study of HPV vaccine uptake in Japan has estimated that vaccine hesitancy between 2013 and 2019 could lead to in excess of 5000 additional cervical cancer deaths there.

The WHO has identified vaccine hesitancy as one of the biggest threats to public health, and the past few years have seen a general global decline in vaccine confidence. We are living in a vaccine-hesitant moment – and in the wake of the covid-19 pandemic, conspiracy theorists are turning their attention to HPV vaccines once again, fuelling numerous myths around the vaccine's safety and effectiveness.

Of course, these claims are completely untrue: considerable evidence shows the safety of the HPV vaccine. As well as preventing 9 out of 10 cervical cancer cases if given by 13, new research suggests HPV vaccines also help to prevent head and neck cancers, which are more common in men and boys.

Despite this, global HPV vaccine coverage is far from ideal, including in some higher-income countries, where vaccine supply and equity is much less of an issue than in lower-income countries. In the US, for example, only around 6 in 10 teenagers are up to date with an HPV vaccine. For HPV vaccines, unlike some others, research shows that uptake can actually be lower among those from more affluent backgrounds.

It is particularly concerning that prominent anti-HPV vaccination voices have also spread disinformation about covid-19 vaccines. For example, well-known anti-vaccination doctors, such as Pierre Kory, spread myths that the HPV vaccine Gardasil wasn't safe. Kory later co-founded the Front Line COVID-19 Critical Care Alliance, which has pushed the use of ivermectin in treating covid-19, something health authorities recommend against. Kory has since had his board certification revoked by the American Board of Internal Medicine.

Conspiracy theories are mutually reinforcing, with research showing how those holding a "conspiracy mentality" often subscribe to a similar system of beliefs (like distrust in authority) or psychological traits (such as feeling alienated).

Misinformation and disinformation are like vectors of disease. It is crucial the public health community finds ways to push back against them, for example through "prebunking", in which exposing people to misinformation builds up their "immunity" to it – that is, their ability to spot and resist it.

We need to rebuild confidence in vaccines, including for HPV. If we don't, vaccine hesitancy will continue to be one of the biggest threats to public health. ▮

Simon Williams is a psychology lecturer and public health researcher at Swansea University, UK

Future Chronicles

A kelping hand In our latest glimpse into the near future, **Rowan Hooper** explains how seaweed was a game changer in getting carbon out of the atmosphere in the 2030s

Rowan Hooper is *New Scientist*'s podcast editor and the author of *How to Spend a Trillion Dollars: The 10 global problems we can actually fix*. You can follow him on X @rowhoop

In Future Chronicles, he explores an imagined history of inventions and developments yet to come.

Invention
Atmosphere-restoring seaweeds

Time stamp
2030s

Tagline
The algae that fed the Great Drawdown

This column appears monthly. Up next week: Chanda Prescod-Weinstein

THE big question, in the mid-21st century, wasn't how to transition away from fossil fuels – that process became self-propelling as renewable energy became ever cheaper – but how to get carbon dioxide out of the atmosphere.

In the end, achieving the Great Drawdown, as it became known, required many different approaches, including biological, chemical and technological methods of removal. This dispatch examines two solutions that used the under-appreciated, near-magical power of seaweed: one through robotics and the other through bioengineering. The robot ate vast algal blooms; the genetic engineering approach modified a seaweed to self-destruct and sink to the ocean floor. Together, they removed a significant fraction of carbon from the atmosphere and stored it in the deep.

The robot was a design inspired by manta rays. Mantas are supremely elegant, but swim gormlessly, with their mouths open, devouring billions of tiny organisms a day. This action suggested a way to harvest a monstrous bloom of seaweed that grew each year in the Atlantic.

The Great Atlantic Sargassum Belt was a vast swathe of floating *Sargassum* seaweed stretching from the Gulf of Mexico to the west coast of Africa, first detected by NASA satellites in 2011. Each year, the algae fed on fertiliser pollution and sewerage runoff and caused ecological damage by swamping corals, choking wildlife and rotting on beaches in huge quantities. In 2019, Mexico declared a "seaweed emergency"; in 2023, the mass was estimated at 12 million tonnes and sprawled across 8000 kilometres.

The solution was to deploy swarms of autonomous ray-like clean-up robots. The AlgaRay robots were first designed at the University of Exeter, UK, in the 2020s. Deployed in swarms in the 2030s, they glided like gigantic mantas through blooms of *Sargassum*, inhaling the algae and storing it in their bodies. The mouth of an AlgaRay could be 10 metres wide, and the body could store 20 tonnes of algae at a time. Now, here's the clever bit. Once its belly was full, the robot dived to around 200 metres. At that depth, the air bubbles in the seaweed were crushed and it became negatively buoyant. The algal payload was released and sank to the ocean

"A modified green seaweed, *Halimeda*, could be selectively deployed, bloom and fix carbon, then sink and die"

floor, where it was effectively "frozen" in low-oxygen carbon storage for at least 100 years.

A single AlgaRay robot, powered by the sun, was able to do this many times a day, sinking over half a million tonnes of algae a year. Cheap to make, a swarm of just a few thousand robots easily cleaned and locked up the biggest annual blooms of seaweed. The ecological impact on the deep ocean was minimal. After all, the ocean contains around 37 trillion tonnes of carbon, 16 times more than the terrestrial biosphere. The ecological and financial relief at the surface was immense.

Yet as much as AlgaRay helped remove carbon, we needed to get more out. That's where the second Big Seaweed idea came in. It involved the genetic engineering of self-destructive seaweeds that buried themselves after blooming.

Kelp, the large brown seaweed that grows up to a metre a day, was already known as a potential tool for carbon sequestration. One report said it could draw down up to 10 billion tonnes of CO_2 per year.

Giant bladder kelp has buoyant bladders of air on its blades. This species was genetically engineered to grow free-floating, and then it could be grown, harvested and sunk in the remote ocean the same way as the *Sargassum*. Other forms of modification became more ambitious.

Caulerpa is a genus of seaweed that spread invasively in many parts of the world in the early 21st century. In the mid-2030s, a version of the alga was engineered to grow in a free-floating form and to precipitate heavy metals into its body. Blooms of *Caulerpa* flourished in polluted waters, growing nodules of metal pollutants until they could be harvested by electromagnet-wielding robots and sunk, or plunged to the deep under the weight of their own nodulation.

Modified species were made to clean up "dead zones" of phosphorus pollution in the Gulf of Mexico. A green seaweed, *Halimeda*, famous for being able to make calcium carbonate, was modified into a free-swimming form. The new *Halimeda*, genetically engineered with a death switch, could be selectively deployed, bloom and fix carbon, then sink and die.

The seaweed renaissance continued as carbon levels fell. The mass farming of kelp forests and other seaweeds boomed, boosting biodiversity, providing nutrient-rich meat substitutes as well as ingredients for alternative plastics and even clothing. Children became able to identify a range of species and ate algae for snacks. Their microbiomes thanked them for it. ▮

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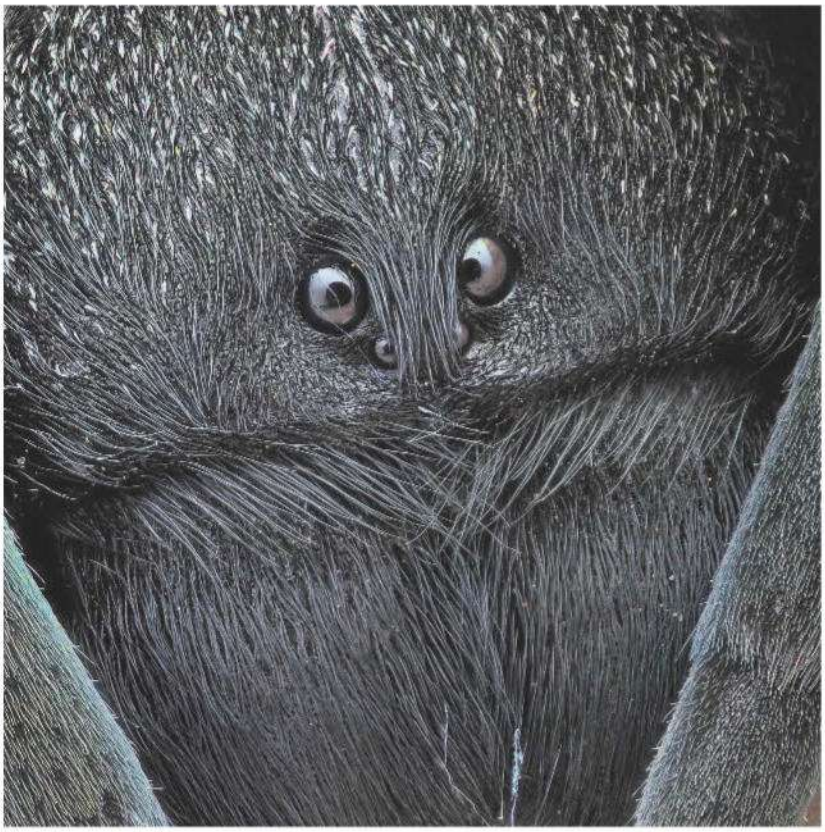

ARIS KOLOKONTES

DANIEL SLY

ALOYS PICHARD

IGNACIO CASTELLANOS

JORIS VEGTER

All in the detail

Close-up Photographer of the Year

EACH year, hordes of spiny toads (*Bufo spinosus*) gather to breed and lay their eggs in freshwater lakes and ponds, mainly across Spain, Portugal and France. Mating is a rough and tumble affair, though, with males often outnumbering females by 5:1. In their desperation to find a mate, males will commonly clasp onto a female already locked into an embrace – known as amplexus – by another mate.

Aloys Pichard captured one of these "breeding balls" in May (far left, bottom), when the toads were crossing a road at night in southern France to reach egg-laying grounds. His photo, along with the others shown here, was shortlisted in this year's Close-up Photographer of the Year contest.

Joris Vegter's image of four gold-tailed *Melitta* bees (*Melitta haemorrhoidalis*) nestling in a flower head is shown at near left, top. *Melitta* bees often sleep together inside bell flowers overnight for warmth. Vegter says he looked in more than 1000 flowers around Groningen in the Netherlands until he found the snoozing bees. "My passion is to share the unseen beauty of the tiny world all around us," he says.

At near left, bottom, is Ignacio Castellanos's image of a male Polyphemus moth (*Antheraea polyphemus*) in an oak forest in Huasca, Mexico. These moths measure more than 15 centimetres from wing tip to wing tip. Daniel Sly's shot of a potbellied seahorse (*Hippocampus abdominalis*) near Bare Island, Australia, is at the top in the middle, with Aris Kolokontes's close-up of a ladybird spider (*Eresus walckenaeri*) to its left.

The competition winners will be announced in January.

Madeleine Cuff

Editor's pick

For the facts, check out the greatest scientist writers

19 October, p 21

From Chris Newton, Berkeley, Gloucestershire, UK

Michael Marshall's piece on non-fiction science books that aren't fact-checked had me nodding faster than a windscreen nodding toy. I work as a writer and editor and have been a journalist, so I understand and value objective truth and the importance of fact-checking. If you read Richard Dawkins, Stephen Hawking and Carl Sagan (among many others), you should get sufficient grasp of the science to spot howlers, hyperboles and unjustified generalisations in works by untried authors.

I have learned not to spend time and money on a new book by someone who isn't qualified in the science in question without a little test reading, if possible. Online booksellers make this possible, as do bookshops. The worst titles aren't always returned after buying, having suffered too much damage in collision with the waste basket.

From Richard Brown, Huntly, Aberdeenshire, UK

A Hong Kong government department I worked with had to fact-check documents and certificates. Errors were common. Once, to our surprise, we received a document that was perfect. It came from Buckingham Palace. We later found that its documents had to cross three desks before issue.

Hold the Arctic ice geoengineering

Leader, 28 September

From David Armstrong McKay, University of Sussex, UK

You suggest that geoengineering is now essential to save the Arctic's ice based on the results of a recent sea ice restoration trial, arguing that "to buy us time and to buttress this delicate habitat from a warming world, geoengineering is probably our only hope".

If this were an early-stage trial for a new treatment of a serious disease, I would be surprised if you would so quickly advocate for its use. Instead, I would expect a promising result to be highlighted along with the potential risks and uncertainties. Time is indeed short, but if the aim is to limit harm to Arctic ecosystems, then we shouldn't rush into understudied climate fixes without better understanding the inevitable trade-offs involved.

Free energy: Perhaps Le Chatelier got there first

19 October, p 32

From Pete Swindells, Wolverhampton, West Midlands, UK

It seems to me that the free-energy principle (FEP) is little more than a restatement of the principle put forth by chemist Henry Louis Le Chatelier: "If a system is subjected to stress, the system will respond in a manner that tends to mitigate the effect of the stress." I can't see that the fuzzy notions of the FEP offer anything beyond this.

On artificial pets, Furbys and how to raise a robot

12 October, p 22

From HildaRuth Beaumont, Brighton, UK

Rowan Hooper's musings on future robot pets brought to mind two things. The first was the Furby, an electronic "pet" developed in the late 90s. It could respond to a variety of inputs with changes to its facial expression and speech. All its abilities were programmed into it and the Furby wasn't connected to outside sources of information. This is different from Hooper's robo-pets, which also aren't connected to the internet but can learn different behaviours by the way their owners treat them, very much like real pets.

It is in line with author Eve Poole's idea of developing relationships between humans and robots by considering how we might "bring up" robots in the same way as we bring up children.

Don't knock TV, a glass of wine and a plate of cheese

5 October, p 39

From Sam Edge, Ringwood, Hampshire, UK

The idea that we should strive to find more effortful leisure pursuits won't suit everyone.

Many of us have very physically or mentally effortful jobs and some, sadly, don't particularly enjoy much of that effort. The last thing they need is to feel guilty for decompressing with TV, music, a trashy novel or other "non-productive" activity. Even those lucky enough to get satisfaction from work effort need downtime.

When my partner retired from a stressful teaching job, she spent a lot of time trying to find a worthy structured activity. It took her a while to realise that this was just causing anxiety. Now, she doesn't worry about how much time is spent gardening, reading, drawing, doing yoga, looking after family, chatting in the pub or zoning out in front of the TV with a glass of wine and a plate of cheese!

Solar sails on the ISS is a great idea

Letters, 19 October

From Sandy Henderson, Dunblane, Stirling, UK

I applaud Eric Kvaalen's idea of using solar arrays on the International Space Station as solar sails that might keep it in orbit. Few places would be better suited to testing designs for solar sails. As for the favoured plan to bring down the ISS, I deplore the mindset of those who would scrap a valuable asset because they can't presently see a future for it.

This scheme is best for tackling wealthy emitters

28 September, p 19

From Mini Grey, Oxford, UK

The richest 1 per cent of the US population is responsible for more carbon emissions than the entire lowest-income 50 per cent. Your article on this advises more climate policies targeting those responsible for the largest emissions, with inheritance and wealth taxes. But there could be a fairer, clearer way to hit them straight in the carbon pocket.

A carbon fee and dividend (also called climate income) puts a price on carbon at source, increasing the price of all fossil fuels, so that running private jets, superyachts and the like gets really expensive.

But here is the key: the revenue is distributed equally to all citizens, with a regular dividend payment. This system is really progressive, benefiting lower earners most. Middle-income earners benefit or break even. Wealth from the 1 per cent will be redistributed to everyone else just by targeting their carbon use.

Could AI one day win the greatest prize, an Ig Nobel?

19 October, p 13

From Don Allen, Winchester, Hampshire, UK

I have three easy tests for whether artificial intelligence has become our scientific equal. It should be able to instigate research, get a paper accepted for publication and, lastly, win, or get nominated for, an Ig Nobel prize. This last task needs an understanding of humour, irony and, sometimes, double entendre.

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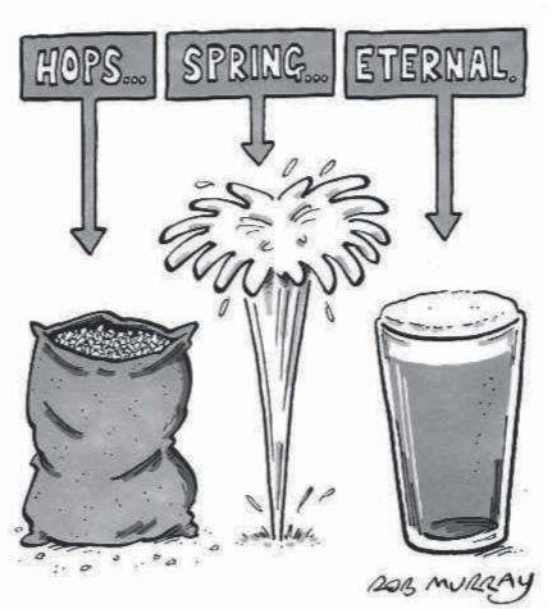

When a Yorkshireman finds a source of pure spring water, he doesn't bottle it. He builds a brewery on it.

In 1863 Timothy Taylor was given the opportunity to buy land over a natural aquifer spring. He did what any good Yorkshireman would, and immediately started work building a brewery. Ever since, The Knowle Spring has been the source of the unique spring water we use to brew our beers. Filtered through layers of black rock and limestone, it is said to taste like melted snow. It's a very pure and consistent water, one of the reasons we are able to brew beer of such reliable quality and taste. After that first sip you might agree.

All for that taste of Taylor's

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New Scientist video
Watch our career-spanning interview with Roger Penrose **youtube.com/newscientist**

Connected, but alone

A biography of Roger Penrose, a major figure in mathematics and physics, salutes his achievements but also shows the human cost, finds **Chelsea Whyte**

Book
The Impossible Man
Patchen Barss
Atlantic Books (UK, 14 November); Basic Books (US, 12 November)

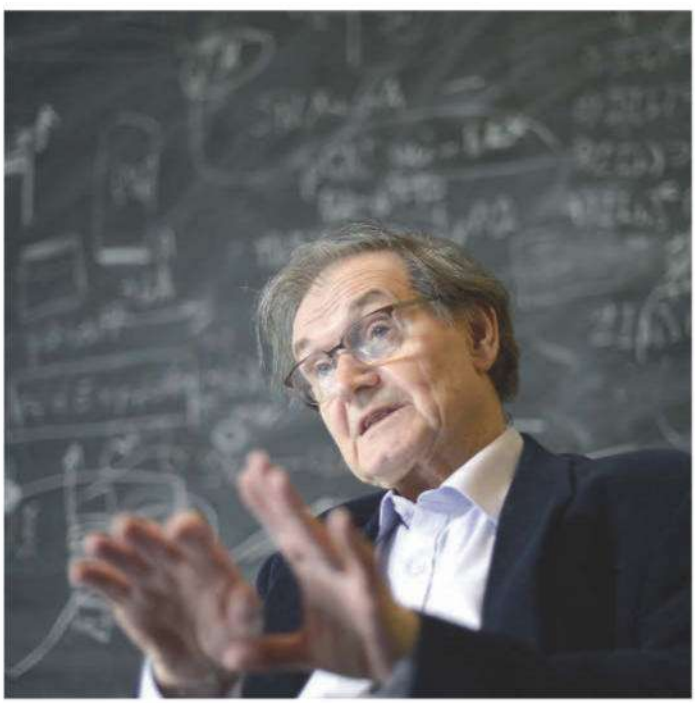
MANY people still believe (and many scientists tell themselves) that genius is a solitary affair, that what they do is so important it merits exemption from everyday life and the obligations of intimate relationships.

As his subtitle suggests, Patchen Barss doesn't endorse this notion in *The Impossible Man: Roger Penrose and the cost of genius*, as he charts the life of one of the most influential physicists of the 20th century. The biography spans Penrose's childhood in 1930s England to his 2020 Nobel prize win and beyond, tracking his professional collaborations and the collateral damage suffered by family and friends.

The first thing that caught me off guard is just how many famous connections Penrose has. His mother's family knew Nobel prize-winning neurologist Ivan Pavlov and composer Sergei Rachmaninoff. His father, Lionel, briefly studied psychology with the psychoanalyst Sigmund Freud and filled the Penrose home with computing pioneers from Bletchley Park. Lionel's brother, Roland, was a surrealist artist who palled around with Pablo Picasso.

Once you get to his professional associations with the great minds of 20th-century physics and mathematics (a stellar list of people who reframed how we think about the universe on every scale), it starts to feel a tad Forrest Gumpian. These connections must have influenced his genius.

One of my favourite such connections is described in the book: Penrose's relationship with the artist M. C. Escher. As a child, I would spend hours getting lost in Escher's world-bending illustrations of fish that turn seamlessly into birds and of endless, impossible staircases. Decades later, when I came across Penrose's work on infinite tiling, I was drawn back to Escher. I only learned later that these two giants were friends and collaborators.



A PA-PICTURED ESK/ALAMY

Roger Penrose, at the Institute of Science and Technology, Austria

"Holding complex shapes in his mind gave him insight into the singularities at the heart of black holes"

Barss reveals how it started. Penrose was attending a lecture on mathematics that he found impenetrable (I can relate) and took a stroll to a nearby museum, where he became mesmerised by Escher's art. This inspired him to create what I declare to be the best shape: the Penrose triangle, three bars that overlap at the corners in impossible ways.

The ability to hold complex shapes in his mind gave him insight into the singularities at the heart of black holes, which, in turn, helped him refine Albert Einstein's theories and inspire Stephen Hawking's work.

Those are just a few of his hits. I read on, making a list in the back of the book until I ran out of room. He inspired the ideas that solidified into the big bang, though he contends that the universe expands and contracts infinitely and has no one start. He also created twistor theory, a way to marry quantum mechanics and general relativity – arguably one of physics' biggest problems.

This could all have been tiresome to read, but Barss mostly doesn't let the maths get in the way. There were only one or two points where my eyes glazed over.

Barss spent five years talking to Penrose nearly every week, about his professional and private life, and was given access to personal letters, excerpts of which reveal a man obsessed with the nature of reality to the detriment of family life. The book takes an unflinching look at Penrose's limited approach to women, whom he seems mostly to regard as muses to inspire his creativity, and at how he isolated himself, especially in later years.

Barss never lets him off the hook for the emotional affair he carried out through much of his marriage or for his broken relationship with his children.

I sometimes found the Penrose of the book aloof to the point of extremity. For example, he was in Dallas in 1963 on the fateful day President John F. Kennedy came to town in a motorcade. I never knew this, but one of the reasons for the visit was to meet Penrose and his colleagues at an event about the future of science in the US.

After Kennedy's assassination, Penrose took a trip to the beach with friends, but rather than grieve with them, he retreated into his work. It was on the drive home that he dreamed up twistor theory.

He is certainly a genius when it comes to the biggest questions we have: where do space and time come from, how did the universe begin and what will happen at the end of it all? You can't really argue otherwise. But perhaps there are other kinds of genius, ones we celebrate far less often, to do with how we show love and find connection. And Barss's unvarnished look at Penrose's life makes clear that he is unlikely to win prizes in those categories. ▮

A powerful lesson

Tackling climate change means radically rethinking energy history – and talk of "transition". **Chris Stokel-Walker** explores

Book

More and More and More

Jean-Baptiste Fressoz

Allen Lane

THE drive towards decarbonisation and the search for alternative, less-polluting sources of energy vex our planet and its politicians and decision-makers. Many wealthy countries are working to strip pollutants and emissions-belching elements out of our industrial processes and individual lives.

This is an age of environmental consciousness. At least that's the argument. But it is one Jean-Baptiste Fressoz, a historian of science and technology at the French National Centre for Scientific Research, rejects entirely in *More and More and More: An all-consuming history of energy*.

It isn't that Fressoz believes climate change is a hoax. Far from it: he sees it as a pressing issue, but he thinks we spend too long praising moves towards a green "transition". He sees this as a fictitious concept, a distortion of the history of energy creation and consumption by the producers out to delay genuine change.

The story most of us know is that we have progressed through ages of energy: we burned wood, replaced it with coal, created electricity using oil and gas and entered the atomic era in the mid-20th century. We are now in the age of renewables.

Except that we aren't, argues Fressoz, in a densely researched polemic designed to shock readers out of their belief in the progress being made by Western countries in reducing environmental impact.

Rather than each successive energy source replacing the last outmoded one, as we reduce overall extraction, each epoch is additive. They are piling on top of each other, pushing consumption ever higher as they feed off the previous sources, and accumulating more and more and more damage to Earth.

Past energy historians have contributed to the problem, Fressoz reckons, by trying to neatly divide the past into discrete eras. Take the purported transition from wood to coal, for instance. Many mine shafts were propped up with wooden props – preferred by miners because they were more disposable than specially designed steel struts and, crucially, because they would start to crack when weak, a useful signal to get out before a mine collapse.

And as coal production tripled in the then Soviet Union between 1950 and 1970, Fressoz points out, so, too, did demand for timber, to the extent that the Soviets struggled to keep up supplies to Ukraine, a big coal producer.

The book is full of facts and stories, which tumble over each other to hammer home Fressoz's main argument: far from getting better, we are getting worse and have much to rethink. Who knew that, according to International Energy Agency figures cited in the book, wood "provides twice as much energy as nuclear fission, twice as much as hydroelectricity, and twice as much as solar and wind power combined"? Or, Fressoz writes, that "technological innovations have never, right up to the present day, caused any flow of material consumption to disappear"?

But despite such astounding data points and a tremendous depth of research, Fressoz isn't a natural storyteller. An existential cry for change needs straightforward, punchy prose, punctuated by killer facts and stats. At times, messages are thrown about in a melange that loses persuasive power.

In part, this is because Fressoz sticks to his principles: we have downplayed our issues by creating neat stories. That said, for his message to hit home, he should meet readers halfway. At his best, Fressoz makes them as voracious to devour his book as to guzzle oil and gas. But the effect can be less an all-consuming history of energy and more an overwhelming flood of words. ▮

Chris Stokel-Walker is a writer based in Newcastle upon Tyne, UK

Coal plants and wind turbines coexist rather than replace each other in Westphalia, Germany

MAURITIUS IMAGES GMBH / ALAMY

New Scientist *recommends*

Tiffany O'Callaghan
US Publisher
New York

My 9-year-old was balancing on the spine of a giant Atlantic sturgeon, while his 6-year-old brother popped his head out from behind its gills. A moment later, they

were chasing each other through a tunnel of its pink ribs.

I had brought them to the **Pier 26 Science Playground**, part of Hudson River Park in lower Manhattan, to run off some energy on a day out in the city. What we found was more delightful than any of us had anticipated.

The huge blue and orange models (pictured) are of two kinds of sturgeon indigenous to the Hudson river, and as well as steps, slides and nets around them, there were signs identifying their anatomy or sharing fun facts. My boys loved learning that sturgeon have been around since the days of the dinosaurs.

And if you need help enticing kids away, it is worth noting that Pier 26 is a few blocks from a favourite photo spot: the FDNY Ladder Company 8 firehouse (still active) on Moore Street – aka Ghostbusters HQ.

RYAN CONNOR

The film column

Talk to me A stellar cast (think Cate Blanchett, Charles Dance) are leaders of G7 countries facing up to an existential crisis. Or not. *Rumours* is a smart, joyous satire about communication, diplomatic nonsense and not coping, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on X @simonings

BLEECKER STREET

In *Rumours*, world leaders tackle a crisis as only they know how

LEADERS of the G7 nations gather on an estate outside the German village of Dankerode in Saxony-Anhalt to thrash out a joint communiqué on an unspecified (but clearly terminal) global crisis.

They used to be the G6 but then Canada joined. No one's too sure about Canada. Its prime minister, Maxime Laplace (Roy Dupuis), keeps having to run off for a good cry. Cate Blanchett plays German chancellor Hilda Orlmann, who brings him what comfort she can. You can tell she is in love by the way she praises the line he is crafting about women and minorities.

Back at the conference table (well, the gazebo – they ran off into the park to avoid the press), a full-on bromance is developing between the leaders of Japan (Takehiro Hira) and France (Denis Ménochet) around the entangled issues of domestic violence and supply chain management.

Nikki Amuka-Bird is Cardosa Dewindt, UK prime minister, brash, friendly and optimistic right up to the moment Maxime forgets to keep his distance ("Forget Rimini!" she implores him – the location of a brief romantic interlude. Maxime breaks a wine glass and runs off, weeping).

The leaders are invited to a photo opportunity with archaeologists excavating bog bodies in the park grounds. This causes tension, not least because the French prime minister insists on going on about his new book, all about the psychogeography of graveyards.

Soon the sun will set, the staff will vanish and the bog bodies will emerge to fecundate the earth (don't ask). Someone called Astrid the Night Queen will stalk the land (that's the rumour, anyway) and the European representative, Celestine Sproul (Alicia Vikander – but Europe's a non-enumerated member, so she doesn't count), will be found stroking a gigantic brain and whispering gibberish into "her nurturing folds".

"The world is dying and what can seven frightened 'children' do but try their best to conjure up a spell?"

What makes this satire mildly amusing is the way it puts seven high-ranking politicians into an absurd situation where they end up behaving like children. What makes this a captivating, joyous and unmissable film is the way it traps them in straitjackets of diplomatic rhetoric. As they run about their patch of forest, fleeing the zombie masses, we see these innocents fall in and out of love, desert and rediscover each other, save and betray one another – and all in the emollient language of the diplomatic joint press release.

The leaders in *Rumours* are basically good. Sometimes they are pompous, or crack under the strain. What binds them is a desperate loneliness. The G7 meetings are about the only times they get to relax with people as unworldly as they are. Inept? Of course they are. We are all inept, if your standard of aptitude is something ridiculous like, oh, being able to save the planet.

The world is dying and what can seven frightened "children" do about that, but try their level best to conjure up a magic spell?

The directors of this unlikely sounding production are hardly household names. Their cinematic cachet, though, can be judged from the starry cast. True, Charles Dance, as the US president, does little more than nap, but he does it with great panache, and Blanchett's comic turn as the lovelorn chancellor is easily one of the best things she has done.

Rumours is a satire about our need to communicate and the shambles we make of things when we try. It is a charming, gentle, wry, intelligent little movie. It isn't going to make the earth tremble. But the zombies are more than capable of doing that on their own. (No, really: don't ask.) ▮

Film
Rumours
Directors: Guy Maddin, Evan Johnson, Galen Johnson
On show in the US; on general release in the UK from 6 December

Simon also recommends...

Film
Dr. Strangelove
Stanley Kubrick
A classic satire of political unworldliness that casts Peter Sellers in three roles, none of them saving the world from nuclear war.

Book
Ratner's Star
Don DeLillo
This madcap tale revolves around little Billy Twillig, a pubescent maths prodigy on whose word the future of the whole world hangs.

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An MSF surgical team at Al-Shifa's burn unit in Gaza city cleans the wound of a child after a burn injury. Photograph © Tetiana Gaviuk/MSF

DR JAVID ABDELMONEIM IS AN MSF DOCTOR RECENTLY RETURNED FROM WORKING IN GAZA.

"At Nasser hospital, we provide trauma surgery and burns care to patients. One Saturday early in my time there, we received hundreds of injured, as well as people who had been killed, following a missile strike.

It was chaos. Our team went to the emergency room. One of the injured was a three-year-old girl. She was breathing and looking at me – so she must be okay, I thought. But as I rolled down her dressing, I found that her entire left thigh was open to the bone.

Seconds later, the doors crashed open. Four to five injured people were brought in, most of them first-aid responders. Among them was a boy who wasn't breathing, so we tried to revive him, but the nurse looked at us and asked: 'Why are we responding to him if he can't breathe? We have to save other lives.' No one had the heart to call it and move on to the next person. He was someone's child. But we had to move on to the next, and then the next, and this continued for another four and a half hours.

In the emergency room, there was blood all over the floor. I had to kneel to see the patients, who were sprawled everywhere because there were no beds left. At the same time, more and more patients were coming in.

EVERY SECOND COUNTS

I've responded to mass casualty incidents around the world, and I know that whether we're working in Gaza, Ukraine or one of the many other conflicts going on globally, it's vital that we act fast.

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Because with trauma care, every second counts. You can buy us vital time."

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MSFR0048

The Botanic Age

We are finally starting to glimpse a lost era of human history when we made tools not from stone but from plants, says **Sophie Berdugo**

THERE are few things more irritating in everyday life than getting something stuck between your teeth. Thankfully, we can reach for a toothpick – and it seems our ancient ancestors did the same. In fact, a fragment of a 1.2-million-year-old toothpick is perhaps the earliest direct evidence we have of hominins using plants as tools.

Our ancient ancestors probably made frequent use of implements made from plants. But finding evidence of this is extremely tough because botanical materials are so quick to rot away. This means the archaeological record of human tool use is deeply skewed towards the much hardier stone.

All this suggests that the origins of human technology could have been profoundly misunderstood. The conventional view is it all started with the first stone tools and the dawn of the Stone Age over 3 million years ago. But what if, even before that, there was a botanical age, one based on woodworking and weaving of plant materials? For some researchers, it is absurd not to think that plants would be part of the story. "Perishable material culture is an essential element in our evolutionary past," says Linda Hurcombe at the University of Exeter in the UK.

Now, we are finally getting a clearer view of this lost age. New techniques are making it possible to find traces of plant-based tools that would otherwise have been missed. And by studying the way modern primates use plants, researchers are getting clues as to how traces of the human Botanic Age might be preserved in the fossil record. All in all, it's a shift that might lead to a radical rethink of the origins of human technology.

There is an undeniable logic behind the burgeoning idea of a Botanic Age. The use of tools made from plants is universal across non-industrialised societies and in our closest ape relatives, so it seems inconceivable that ancient hominins overlooked these versatile resources. That is certainly Hurcombe's view. In fact, she and other researchers like her think that implements made from organic materials make up the "missing majority" of artefacts upon which the foundations of the Stone Age probably rest. A small but growing number of these researchers are dedicating themselves to finding evidence of this undiscovered era of human evolution.

So far, the oldest direct evidence we have of this period is that fragment of ancient toothpick. This was discovered in 2016 when Karen Hardy at the University of Glasgow, UK, and her colleagues found a tiny piece of non-edible wood in the fossilised tooth plaque of a 1.2-million-year-old hominin from Atapuerca, Spain. The fragment was next to characteristic straight scratches on the teeth, called interproximal grooves, which scientists believe indicate repeated use of prehistoric toothpicks.

But it is likely that plant-based tools and implements were in use far earlier than this. Indeed, in the 1970s, the feminist anthropologists Nancy Tanner and Adrienne Zihlman suggested that containers such as baskets were among humanity's earliest possessions. They were pushing back against the "man the hunter" dogma that placed men and their activities at the forefront of hominin evolution. "It wasn't really picked up on... but it was a vastly important insight," says Dean Falk at Florida State University.

Their idea was that having a way of securely carrying and storing gathered food and water would have been fundamental for hominins from very early on. This hypothesis extends to something else that would have been equally important to carry: babies. It is thought that this need stemmed from a uniquely human transition that started more than 6 million years ago, well before the Stone Age – the move to walking on two legs.

With the transition to bipedal walking came a corresponding shift in the position of the big toe that reduced our ability to grip with our feet. This, combined with losing most of our body hair, meant that babies could no longer cling onto their mothers like other primates do – and dropping your baby is a pretty big setback, not least from an evolutionary perspective.

The earliest tools

Falk, who is writing a book on humanity's Botanic Age, says that baby slings were a clear solution to this problem and that "baskets on the hips", as she calls them, may have been the first human-modified plant tools. "Even just a strap of vine or grass could have been the first slings," she says. For Falk, this would have been "an obvious light-bulb moment" for early hominins. This idea is supported by ethnographic evidence showing that baby slings are widespread among contemporary hunter-gatherer populations, with caregivers using organic materials such as plants, animal skins and fabrics to secure infants to their chests or backs.

The problem is that there is no direct archaeological evidence for this early technology, and there may never be. "It's tantalising, but until somebody comes up with some other way to get at that question, I don't know what we can do with it," says Dietrich Stout at Emory University in Atlanta, Georgia. We aren't going to find something used as a baby sling by ›

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hominins that far back in time, he says.

Ancient hominins must have started to use containers at some point, but even if these survived, how could you prove that prehistoric people used, say, a leaf as a cup, like modern-day chimps do? "Archaeologically, we have this roof, where we have really clear evidence for containers only after about 100,000 years ago," says Michelle Langley at Griffith University in Australia. This came from the discovery of an ochre-processing workshop at Blombos cave in South Africa, where a liquid ochre paste was produced and stored in abalone shells. All traces of the containers that must have been used before this time have disappeared.

But, very occasionally, botanical artefacts are discovered. Currently, the oldest wooden artefact modified by hominins seems to be an approximately 750,000-year-old polished willow plank unearthed in the 1990s in northern Israel. But this is far from clear-cut, and Annemieke Milks at the University of Reading, UK, says the find needs to be reassessed using modern techniques to double-check that it is indeed an early example of woodworking. That makes last year's discovery of 476,000-year-old notched logs at Kalambo Falls, Zambia, perhaps used as part of wooden structures, the earliest unequivocally hominin-modified botanical artefact.

There is then a gap of a few tens of thousands of years before the next evidence appears: the Clacton spear found in Essex, UK, from 400,000 years ago, four other wooden tools from Kalambo Falls including a digging stick and a wedge from 324,000-390,000 years ago and the Schöningen spears and throwing sticks found in Germany, which date back 300,000 years.

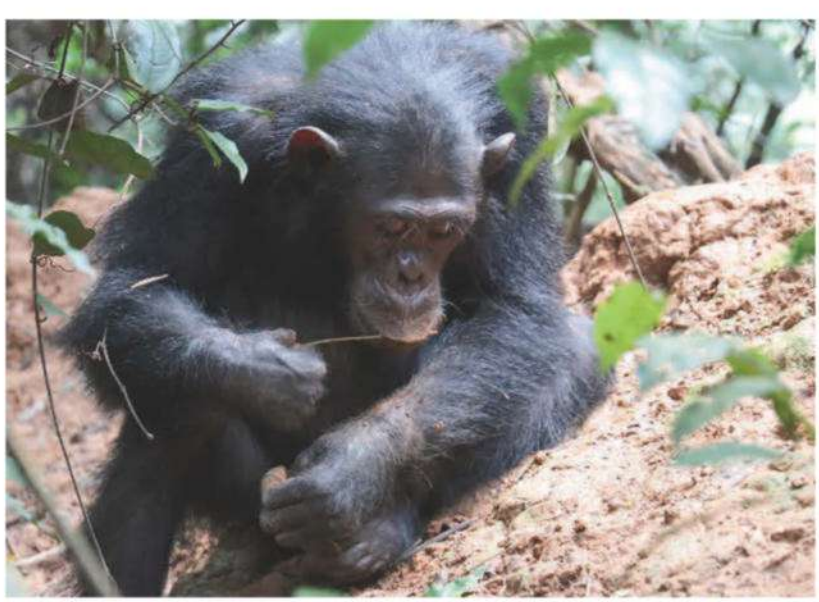
At the moment, researchers are relying on these lucky finds to piece together humanity's Botanic Age. But Bruce Hardy at Kenyon College in Ohio says that "if we're going to make any more headway in palaeolithic archaeology, we have to find a way to detect those perishable materials". To do this, he says, we need to get out our microscopes.

In 2016, Hardy was handed a stone tool with a little white fleck on its underside that had been dug up from a Neanderthal site in south-eastern France. He placed it in a vacuum chamber and fired up a scanning electron microscope. Incredibly, Hardy could discern plant fibres that were clearly the remnants of an intricately made 50,000-year-old three-ply twisted thread. He could even identify the long structure of the cells in enough detail to say the fibres were constructed from the innards of a conifer tree.

Hardy thinks the cord was saved by being beneath the stone tool it was found attached to. Although the twisted fibre could be completely unrelated to the tool, the stone stopped the decay process by acting as a protective barrier from groundwater. Other plant residues can also stick to stone for millennia, such as microscopic silica particles called phytoliths. The oldest evidence of woodworking tools comes from phytolith remains attached to approximately 1.5-million-year-old stone tools called hand axes from Tanzania, which suggest they were used for chopping wood, perhaps from a type of acacia.

But Hardy says that many researchers who study stone tool finds may be inadvertently destroying these crucial botanical residues. When looking at the fine marks left behind from repeated activity, known as use-wear analysis, researchers often scrub away anything on the stone's surface to get a more fine-grained image of the damage. "Once we wash it, we lose that evidence," says Hardy.

"Was there a technological Botanic Age before the dawn of the Stone Age?"



ALEJANDRA PASCUAL-GARRIDO

Chimpanzees use stick tools to harvest termites

GRAHAM PRENTICE/ALAMY

Baby slings made from organic materials could have been humanity's earliest technological creation

"There's likely to be so much more stuff out there. If you don't look for it, you don't know."

This isn't to say that use-wear analysis isn't a valuable source of indirect evidence for prehistoric plant processing. In fact, this is how Hermine Xhauflair at the University of the Philippines Diliman and her colleagues discovered that 39,000-year-old stone tools from Tabon cave in the Philippines had been used to strip plants. But "the devil's in the details with all of that kind of research", says Stout, and often the evidence is debatable as to whether the particular pattern of modification was caused by a certain behaviour. "It's easier to find something if you know what it looks like," he adds.

To do this, researchers are turning to our living, tool-using, primate cousins for inspiration. For instance, Alejandra Pascual-Garrido at the University of Oxford is looking specifically at chimp tech that early hominins are known to have also used, and is tracking the signatures they leave behind. This new strand of primate archaeology, what she calls the "archaeology of the perishable", is focused on establishing the use-wear patterns left when making and using plant tools.

Gone fishing

Pascual-Garrido's research focuses on chimpanzees using wooden probes to fish for termites, which archaeological and ethnographic evidence suggests hominins also used. Currently, the oldest evidence for this behaviour comes from research from 2001 showing that *Paranthropus*, an ancient hominin that lived in southern Africa, used bones to dig into termite mounds to obtain a protein-rich meal up to 1.8 million years ago. Although this isn't a botanical find, delicate probes made from plants are much less likely to preserve over such long periods.

So, rather than looking for the sticks themselves, archaeologists may have more luck keeping an eye out for fossilised versions of where the tools were sourced from. Pascual-Garrido is trying to form a library of the scars on the trees that form when chimps make their tools, for archaeologists to compare finds with.

Between 2014 and 2016, she visited three Tanzanian chimpanzee communities and discovered their recently used termite-fishing spots. Turning her back on the mounds, she inspected the surrounding trees. She found highly distinctive scars, with the outer bark of thin branches having a 60 to 80-centimetre-long and 0.5-centimetre-wide strip peeled off, as well as incisor bite marks from where the chimp used its teeth to remove the strip for use as a probe.

These bark scars were still identifiable after three years, showing the lasting nature of these signatures. That is critical because it might take some time before the living tree becomes part of the archaeological record. Katarina Almeida-Warren, who collaborates with Pascual-Garrido at the University of Oxford, says that tracking how these scars change over time is key to being able to find any preserved archaeological traces. This involves following how the colour of the scars transforms as the bark heals and watching how the tree then regenerates itself.

Pascual-Garrido has spent the past two years back with the Tanzanian chimps and says her early findings are showing that the apes "leave characteristic traces in the environment that can be identified for much longer than we currently think". This gets us one step closer to being able to identify botanical evidence of termite-fishing in the early human record.

Meanwhile, another group of researchers is hunting for a different type of plant tech: pounding tools. Currently, the earliest hominin stone tools are a selection of chunky, 3.3-million-year-old stones called cores, used for pounding open hard resources, perhaps nuts or bones. Modern-day chimpanzees in Taï National Park, Ivory Coast, use these kinds of bulky stones to crack nuts, but, crucially, they also use wooden hammers, selecting which medium to use according to the nuts' properties. Lydia Luncz at the Max Planck Institute for Evolutionary Anthropology in Germany thinks it is reasonable to speculate that early hominins would have also used wooden hammers and is leading a project that is searching for these early wooden pounding tools. "Most people doubt that they can be found in the archaeological record," says Luncz. "We're a small crowd who believe they can."

By looking at chimps' discarded wooden hammers, Luncz and her team found that this repeated percussive activity leaves distinctive traces. The grain on the surface becomes much less horizontal at the points of impact and the wood forms obvious pits. Critically, they discovered there is also irreversible damage to the internal cell wall structures, which become compressed in a highly diagnostic way. Internal cellular anatomy is preserved in fossil wood, so these findings could help us spot evidence of pounding in the ancient human record. That is what Luncz and her colleagues are working on now.

Although rare, hundreds of pieces of fossilised wood that are over a million years old have been found at African hominin sites. Luncz's team is looking at pieces of fossil wood from Koobi Fora in northern Kenya, a site known as "the cradle of mankind", where many hominin species lived from around 4 million years ago. She says she is hopeful that by applying the results of the chimp research to these remains, she and her team will be able to identify pounding in the archaeological record.

All of these efforts mean there has been steady, if gradual, progress in revealing humanity's possible pre-Stone Age botanical period. From this, we may one day learn that species we had previously assumed weren't tool users, because their fossil remains hadn't been found with any stone tools, were actually tech savvy.

Hunting for traces of humanity's earliest botanical possessions is certainly far more challenging than unearthing stone artefacts, but it has the potential to shine a completely new light on the lives of our ancient ancestors. "It will open up some really interesting questions," says Almeida-Warren. ▮

Sophie Berdugo is a freelance writer and evolutionary anthropologist based in London

What's cooking?

Supermarkets now have an overwhelming choice of oils to grease our pans and dress our dishes – but which is healthiest? **Jasmin Fox-Skelly** investigates

WHETHER you are roasting a chicken in the oven, browning onions in a frying pan or choosing a spread for your toast, oils are at the heart of our culinary activity.

We have a dizzying array of choice. From sunflower to flaxseed, avocado to coconut, around 30 varieties of oil are now used for cooking. Your decision on which to use could have a profound effect on your health, with consequences for your cholesterol, blood pressure and risk of cardiovascular disease.

If you believe the headlines, then palm oil is out, sunflower oil is on shaky ground and there seems no end to the benefits that extra virgin olive oil brings to the table. But are these claims backed up by solid science? And how do the health effects of these products weigh up against their environmental costs?

First, some chemistry. Cooking oils contain fats, which are made from long chains of carbon atoms linked together. Saturated fats, found in red meat and dairy, are so named because each carbon atom is linked to the next by a single bond. The remaining electrons of each carbon atom are then available to form bonds with hydrogen atoms – making the molecule fully "saturated" with this element. This structure makes these fats very rigid and stable, which is why butter and lard are solid at room temperature.

Unsaturated fats, commonly present in plants and oily fish, have at least one double bond between neighbouring carbon atoms, which reduces the number of bonds that can be formed with hydrogen atoms. If there is only one double bond, it is monounsaturated; if there are more, it is polyunsaturated. The double bonds make these fats more fluid, which is why they are usually liquid oils. Most cooking oils are made up of a blend of different fats, including both saturated and unsaturated varieties. This is a good thing, since both have important biological functions. "We need fats to help us absorb certain vitamins in the gut," says Richard Hoffman, a nutritional biochemist at the University of Hertfordshire, UK. "They also form an essential part of the lipid bilayer that makes up the membrane of each of our body's cells."

But as with so much in life, it is a question of balance. While we need some saturated fat in our diet, most people consume too much. "Tropical oils, such as palm oil and coconut oil, are very high in saturated fatty acids, and the types of saturated fatty acids they contain are known to raise cholesterol," says Sarah Berry, a nutritional scientist at King's College London. This "bad" or low-density lipoprotein (LDL) cholesterol can kick-start the process of atherosclerosis – the buildup of plaques in the arteries – which can raise the risk of heart disease and stroke. For that reason, Berry believes they should be avoided.

Polyunsaturated fats are generally considered to be healthier. There are two types commonly found in cooking oil: an omega-3 fatty acid called alpha-linolenic acid, found in flaxseed and rapeseed oil, and an omega-6 fatty acid called linoleic acid – which is particularly prevalent in sunflower and cornflower oil. Both types of fats are packed with antioxidants and are linked to health benefits such as improved insulin sensitivity.

There is some controversy and disagreement about their relative merits, however. Some nutritionists believe that omega-6-rich oils could cause chronic inflammation – the driving force behind many conditions affecting Western societies, such as heart disease, type 2 diabetes and even Alzheimer's. These concerns arise from the fact that omega-6 fats can be broken down by the body into arachidonic acid, a pro-inflammatory molecule.

Omega-6 fats also compete with omega-3s for their place in the cell membrane. This is a problem because cell membranes – particularly those in your retina, brain and heart muscle – rely on omega-3s to function optimally. The high number of double bonds in omega-3s, coupled with how these double bonds are positioned, makes them more fluid than other fats, and so their presence also increases the fluidity of the cell membranes. This helps neurotransmitters and hormones bind to membrane receptors more effectively, allowing messages to be quickly sent around the body.

For these reasons, it might seem sensible to prioritise oils rich in omega-3. In one randomised controlled trial, participants were asked to take a teaspoonful of flaxseed oil – which contains up to 45 per cent alpha-linolenic acid – with each meal. After 12 weeks, the participants had lower LDL cholesterol and blood pressure compared to a control group taking the omega-6 linoleic acid.

It is worth noting, however, that the omega-3 fats with the greatest benefits for health aren't present in cooking oils. ›

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They are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), found in oily fish such as mackerel, salmon and sardines. Both of these are longer and more unsaturated than alpha-linolenic acid, so they have much more of a fluidising effect on cell membranes. While our bodies can convert alpha-linolenic acid into EPA and DHA, it isn't an efficient process.

"Fish omega-3s lower blood pressure, lower inflammation and they're good for heart and brain health," says Philip Calder, a nutritional immunologist at the University of Southampton, UK. "But you would never cook with fish oil. The plant omega-3s behave a little bit like fish oil and have some of those effects, but they are less potent."

One oil to rule them all

In any case, the idea that omega-6 vegetable oils are inherently harmful has been contested. For example, a 2020 review concluded that higher levels of omega-6s, particularly linoleic acid, are associated with a reduced risk of cardiovascular disease and type 2 diabetes. So there may be no need to throw out your sunflower or cornflower oil just yet. "I think it's perfectly healthy to cook with these oils," says Berry. "They are packed with lots of vitamins and have antioxidant properties. Plus, we know that the polyunsaturated fatty acids in some of these seed oils can help reduce cholesterol."

Adding further complications are the effects of cooking. Fats at room temperature behave very differently to fats heated up in a frying pan. As unsaturated oils are less stable, they break down at lower temperatures. The point at which the oil breaks down is called its "smoke point".

The number of double bonds between carbon atoms means that polyunsaturated fats are more readily oxidised when heated. This can create a rancid taste – which means that omega-3-rich products like flaxseed oil are generally unsuitable for cooking. Even more problematically, oxidation releases extremely reactive chemicals called free radicals, which attack living tissues.

One particular compound of concern is 4-hydroxynonenal, which is thought to contribute to type 2 diabetes, atherosclerosis and cognitive degeneration. The longer you heat oil, and the more you reuse it, the more of this compound builds up. "If you go around the back of a not-particularly-good pub restaurant and smell the kitchen, and it smells rancid, then you know that they're reusing their oils and cooking their oils at too high a temperature," says Hoffman.

We can minimise the risks in our home cooking, however. Provided you avoid heating above an oil's smoke point and don't repeatedly use the same oil for frying, then vegetable oils should be considered safe, says Berry.

Missing from all these analyses, however, is a surprising outsider, extra virgin olive oil, which is neither a saturated nor polyunsaturated oil. Instead, extra virgin olive oil consists almost entirely of oleic acid – a monounsaturated fat – and there is a growing consensus that it may be the healthiest oil of all.

In the early 2000s, over 7000 people in Spain aged 55 to 80 were enrolled onto the Prevención con Dieta Mediterránea (PREDIMED) study. One group followed a standard Mediterranean diet supplemented with large amounts of extra virgin olive oil. These participants were essentially given a 1-litre bottle of extra virgin olive oil per week with the recommendation to consume at least 4 tablespoons per day per person. Importantly, they didn't just drizzle the oil on salads – they were encouraged to cook with it too.

A second group ate a Mediterranean diet supplemented with nuts, while the third was told to reduce their dietary fat intake. All participants also received group and personalised dietary advice sessions. The results showed that, over a period of five years, consuming high amounts of extra virgin olive oil reduced a person's risk of having a heart attack or stroke by 30 per cent relative to those on the low-fat diet.

> "Consuming extra virgin olive oil reduced a person's risk of heart attack or stroke by 30 per cent"

A review published in 2023 came to similar conclusions, finding extra virgin olive oil consumption is linked to lower blood pressure, higher levels of "good" cholesterol and lower levels of "bad" cholesterol – all important indicators of cardiovascular health. "The evidence is clear – extra virgin olive oil is by far the healthiest oil to cook with," says nutrition scientist Miguel Martínez-González at the University of Navarra in Spain, who led the PREDIMED study.

So why is extra virgin olive oil so good for you? Its monounsaturated fat may just be one small factor in its benefits. Unlike other cooking oils, which are extracted using chemicals and high temperatures, extra virgin olive oil is made by squeezing, grinding and pressing raw olives. This means that the product is high in polyphenols – molecules made by plants to protect themselves against stress. Polyphenols are antioxidants, which means they mop up free radicals, reducing inflammation. "They prevent fats oxidising in the body, particularly the bad form of cholesterol, LDL. That protects the body

JEFFREY GREENBERG/UNIVERSAL IMAGES GROUP/GETTY IMAGES

Diets rich in extra virgin olive oil may protect us from high blood pressure

TOM STODDART/GETTY IMAGES

ANGEL GARCIA/BLOOMBERG/GETTY IMAGES

Left: An olive grove in Alentejo, Portugal; Below: Bottles of olive oil on a conveyor belt in Cordoba, Spain

against atherosclerosis," says Hoffman.

Extra virgin olive oil is different to virgin olive oil and standard olive oil, which are manufactured using heat and industrial chemicals. This processing can remove the majority of polyphenols, which is why many experts recommend that we opt for extra virgin over the lower grades. Although cooking may destroy some of the polyphenols, the PREDIMED trial suggests that it is still superior to other fats, provided that you avoid the smoke point.

The cake factor

Any dietary change will face some barriers to uptake. The four tablespoons of extra virgin olive oil a day that were consumed in the PREDIMED trial, for instance, would be considered quite normal in a country like Greece, where a family might get through a bottle every two weeks, but it may seem excessive for the typical consumer in the US or UK. The polyphenols in extra virgin olive oil can also give it a fragrant flavour, which may be undesirable for some palettes.

Price may be an additional issue. "A lot of people probably won't buy extra virgin olive oil just because it's too expensive, so I would say rapeseed oil is probably the second-best to use," says Hoffman. "It contains high levels of monounsaturated fat, which is a good thing, but unfortunately it doesn't contain the high level of antioxidants found in extra virgin olive oil, so it doesn't score quite as highly."

Almost all liquid oils will also face some limitations to their culinary uses. "Solid fats give structure and texture to a cake," says Catriona Liddle at Queen Margaret University, Edinburgh. "If you make biscuits with butter, you either rub it into the flour, or you can cream it. But you obviously can't do that with a liquid oil."

That's why, if you walk down a supermarket aisle selling ready-made cakes and pastries, you will notice one ubiquitous ingredient: palm oil. Palm oil is packed with saturated fats, so it has a high melting point and can be used as a solid fat. It is also cheaper than butter and has a much longer shelf life. It can be blended, behaves well when heated and helps preserve packaged foods. But it is also a major driver of deforestation, contributing to global warming and threatening the habitats of endangered species like the orangutan. It is also unhealthy due to its high saturated fat content. Several researchers are trying to come up with alternatives.

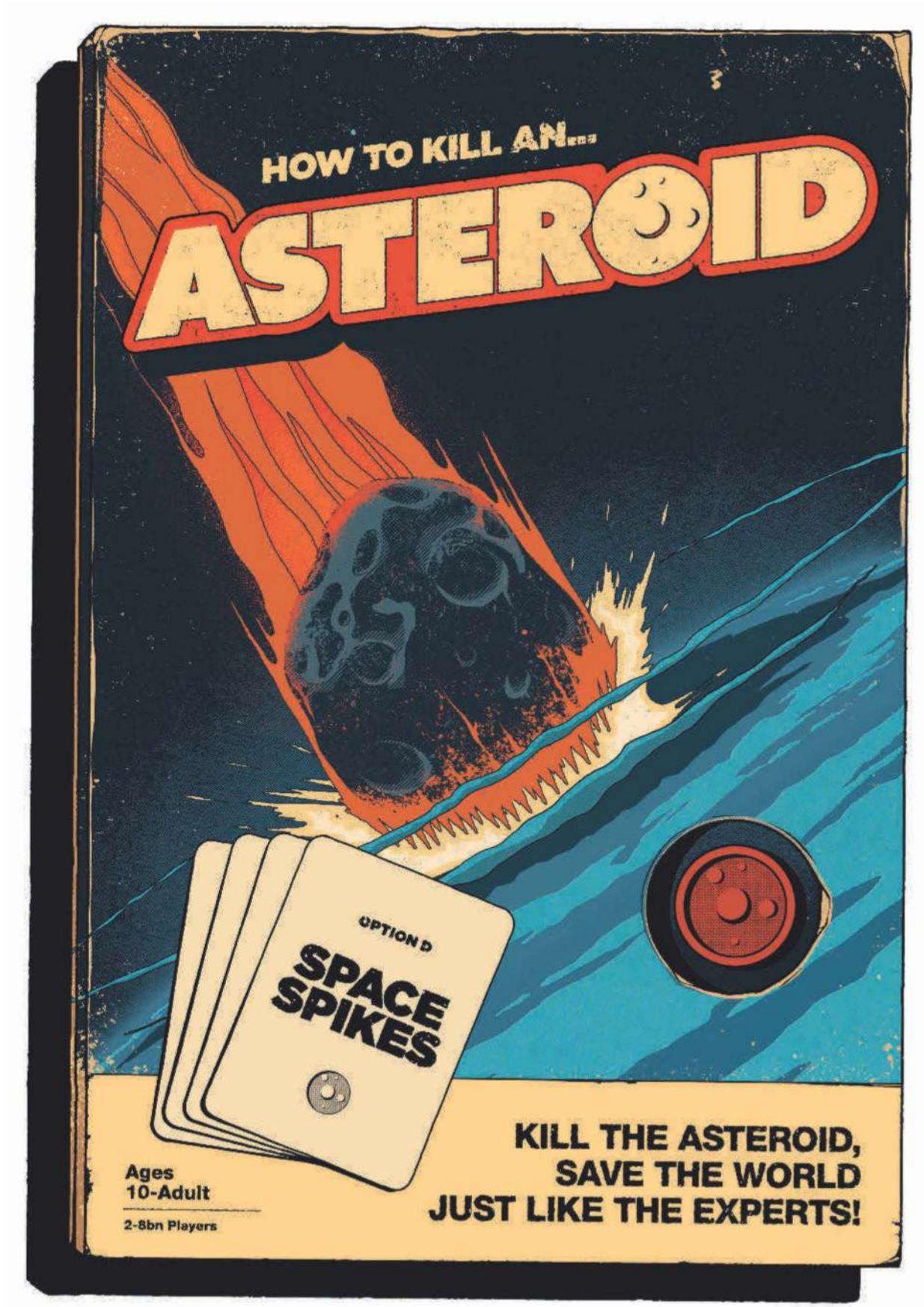
For example, Liddle and her colleagues have developed a new ingredient, PALM-ALT, to replace palm shortening, an ingredient used in the baking industry that is derived from palm oil. PALM-ALT is 100 per cent plant-based and contains a mixture of rapeseed oil, fibres and a byproduct from the linseed industry. It contains 88 per cent less saturated fat than palm shortening, but as it is semi-solid, it still helps maintain the texture, flavour and colour of baked goods. So far, the team has used the ingredient to make cakes, biscuits, bread, doughnuts, cookies and flapjacks.

A panel of taste testers was given either PALM-ALT baked goods or the same goods made with palm shortening. "People couldn't identify a significant difference; it tastes the same," says Liddle, who along with her team is looking at ways to commercialise the ingredient.

Elsewhere, C16 Biosciences, a spin-out company from the Massachusetts Institute of Technology, has developed a palm oil alternative for the cosmetics industry, called Torula oil, that has the same properties as palm oil but without the environmental impact. The oil is made by yeast through a fermentation process. The company is now looking to design palm oil alternatives for the food industry, which they hope to use in ice creams, chocolate and pastries.

Such developments will only add to the already burgeoning range of products available to us. The scientific research can give us some guidelines, but there is still room for plenty of flexibility based on our culinary aims and gustatory preferences. "When you're looking at an oil, I think it's a case of thinking what am I using it for and what taste do I like?" says Berry. "As long as it's not a highly saturated fat or oil, I think any oil is going to confer some health benefits. But if you want the added boost of polyphenols, then extra virgin olive oil is the top choice." ▮

Jasmin Fox-Skelly is a freelance science journalist based in Cardiff, UK


HOW TO KILL AN...
ASTEROID
OPTION D
SPACE SPIKES
Ages
10-Adult
2-8bn Players
KILL THE ASTEROID,
SAVE THE WORLD
JUST LIKE THE EXPERTS!

Asteroid adventure

When a killer asteroid heads towards Earth, what should humanity do? Join a choose-your-own-adventure game to find out, with the help of **Robin George Andrews**

HIDING somewhere in the gloom of space, there is a gigantic asteroid on a collision course with our planet. If we don't spot it and somehow thwart its arrival, it will pierce Earth's atmosphere at 60,000 kilometres per hour and hammer into the ground, vaporising anything it touches.

With millions of asteroids hurtling through the inner solar system, the threat is inevitable: sooner or later, an impact will happen. But that doesn't mean Earth has to be a sitting duck. A global community is engrossed in planetary defence, carefully planning how to fend off these extraterrestrial interlopers when they show up – or at least minimise the carnage.

Among other things, this work has involved scanning the sky for threats and testing missions to knock asteroids off course. But it also includes a surprising amount of role-playing, where teams war-game asteroid impact scenarios. "In the real world, we haven't really gotten to this stage where we actually have to design and build missions, so that's why we need these exercises," says NASA's Paul Chodas, who runs many of the role-plays. "They make you think about details that you would not otherwise think about."

Over the coming pages, you will be in the hot seat in a choose-your-own adventure version of one of these role-playing games. You will decide how to react as the asteroid bears down upon us. Whether you opt to slam a spacecraft into it, use sunlight-absorbing paint to shift its path, or simply blow it to smithereens, you will find we have more options than you might think – but not all of them will save the world.

Before we begin, there are a few things you need to know about planetary defence. When it comes to asteroid impact emergencies, there are two important factors: "How much time do we have, and how big is it?" says Leviticus Lewis, the Federal Emergency Management Agency liaison to NASA's Planetary Defense Coordination Office. The more time you have, the more options that are available to try to prevent the impact. And the asteroid's mass determines not only what sort of mission you would launch to try to combat the threat, but also just how destructive the impact may be should it fail.

A 1-metre-wide asteroid would burn up harmlessly in the atmosphere. A 20-metre asteroid would explode in mid-air, implode windows over a huge radius and cause mild to moderate structural damage. At 140 metres, the asteroid would strike the ground with enough impact to annihilate a large city. Anything a kilometre or more across could cause continental or global-scale devastation.

When it comes to actually protecting Earth from an asteroid, we aren't flying completely blind. In 2022, NASA's Double Asteroid Redirection Test (DART) slammed an uncrewed spacecraft into an asteroid named Dimorphos – which is 160 metres across but not heading towards our planet – and changed its trajectory slightly, suggesting that we could swat a space rock away in a real emergency. Methods other than this have yet to be tested, but the success of DART was a good omen for our chances against a genuine asteroid threat... so long as we have enough time and information to combat it effectively.

Now, let's play. Remember, when you reach an ending, you can start again and explore the other storylines. And don't forget the final debrief on page 43.

An asteroid of unknown size is heading towards the planet, but has yet to be detected.

First, flip a coin.

If **HEADS**, go to the ALPHA TIMELINE (page 42)

If **TAILS**, go to the OMEGA TIMELINE (page 43) ›

RUPERT GRUBER

It isn't good news. In this timeline, there hasn't been significant investment in observatories that search the sky for potential threats, so you didn't spot the asteroid until just two years before it is projected to hit Earth. It could be anywhere from 40 metres to 400 metres across, making deciding on a mitigation campaign tricky – and it is unclear how much damage an impact will cause.

With so little time before the asteroid hits, you only really have two options. You could try to deflect it so it flies harmlessly past Earth or you could disrupt it with great force, ensuring it fragments into tiny particles, with any larger shards missing the planet.

"It's not going to be like *Armageddon* or *Deep Impact*," says Lewis. Choosing what to do will take time and deliberation, and sending astronauts to battle the asteroid face-to-face will do you no good. "Some hard choices are going to have to be made."

To DISRUPT the asteroid, go to A

To DEFLECT the asteroid, go to B

A: DISRUPTION

To be sure you smash it thoroughly, so that most or all of the asteroid's splintered mass avoids Earth, you opt for a spacecraft armed with a nuclear weapon. Even faced with imminent peril, it still takes months for the world's space agencies and governments to agree to send a nuke. There are concerns that the spacecraft may explode in mid-air, scattering radioactive debris all over the place; certain nations suspect that a nuclear-armed spacecraft could be a pretext for a military attack; and some scientists worry that if the disruption attempt fails, you have just turned the asteroid into a radioactive rocky missile.

Intentional disruption "is less predictable compared to pushing it a little bit. You would want to be sure that there aren't any boulders or components bigger than [around 20 metres] hitting the Earth," says Jason Pearl, a physicist and planetary defence researcher at the Lawrence Livermore National Laboratory in California. But, ultimately, the world's spacefaring nations agree on the nuclear disruption option, rather than standing idly by.

Your scientists quickly calculate how powerful a nuclear explosion might be required to achieve a successful disruption, even though they still can't be sure of the asteroid's exact size. Did they get it right?

Flip a coin.

If **HEADS:** DISRUPTION FAILS

Because you are in a rush, and because of the geopolitical infighting, the nuke you pick is too puny to succeed. When it explodes, the asteroid breaks apart into multiple large fragments. Some miss Earth, but several don't, causing immense damage around the world.

If **TAILS:** DISRUPTION SUCCEEDS

Phew. The nuke is powerful enough, and the asteroid is serendipitously small enough, that almost all the asteroid shatters into minuscule particles that fly away from Earth. The few larger fragments that are left either burn up in the atmosphere as they hurtle towards Earth or land in the ocean. You got lucky this time.

B: DEFLECTION

You are opting to deflect the asteroid, but because you can't get a lock on it with planetary radar until a couple of weeks prior to its impact, and with limited observations, you still can't be sure of its dimensions. Continuing observations have now shown that it is between 70 and 160 metres across, so it could annihilate a town, or it could damage a whole country.

Do you want to use DART-style spacecraft called kinetic impactors? Given the urgency of the situation, you would need to use a fleet of these craft to even have a chance of shifting the asteroid away from Earth.

Or do you choose a nuclear warhead to deliver a more efficient punch? The idea would be to park the nuke-armed spacecraft near one side of the asteroid and detonate the warhead, causing a violent spray of debris that would propel the asteroid away from Earth.

To use a NUKE, go to C

To use a KINETIC IMPACTOR, go to D

C: NUKE-BASED DEFLECTION

Your attempt is close to working, but no cigar. Although the asteroid is deflected, it isn't by quite enough to push it entirely out of Earth's way. It is still going to hit, only you have accidentally saved one area of the planet to doom another.

In many cases, when facing down an asteroid, spacefaring nations will say "we've got nothing to lose. Let's go for it," says Lewis. But sometimes it may be better to leave the asteroid alone and simply evacuate the area it is expected to hit, once you know where that is.

"If you deflect it slightly, but not enough, then nobody wants to be left holding the responsibility for saving Japan, but destroying eastern Europe or something," says Cristina Thomas, a planetary scientist at Northern Arizona University and DART team member.

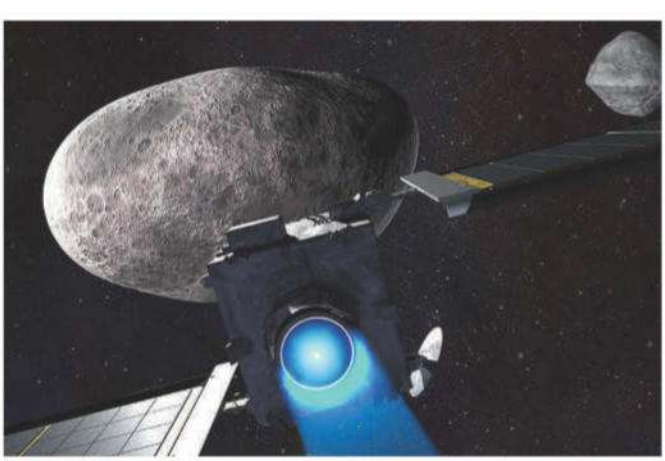
Conspiracy theories about the asteroid being purposefully aimed at a particular country abound, and global politics is thrown into pandemonium – not exactly a great outcome.

D: KINETIC IMPACTOR DEFLECTION

Flip a coin.

If **HEADS:** You launch a dozen kinetic impactors, but only five of them reach the asteroid – which turns out to be 100 metres across – only partially deflecting it. The space rock hits a city.

If **TAILS:** Nine of the 12 kinetic impactors hit the asteroid, enough for it to be fully deflected. The asteroid flies between Earth and the moon; astronomers are abuzz for weeks watching it go by, then everything goes back to normal.



NASA

NASA's DART mission showed we can shift an asteroid

AJ PICS/ALAMY

New Scientist video
Watch films about NASA and ESA's asteroid missions at youtube.com/newscientist

Bruce Willis won't be able to save us from an asteroid this time

TAILS: OMEGA TIMELINE

In this universe, the world's powers have proactively invested in an extensive network of ground-based, asteroid-seeking observatories. You also have a space-based infrared asteroid-hunting observatory, the Near-Earth Object Surveyor (which NASA is working on right now in real life). NEO Surveyor finds near-Earth asteroids quickly, plus its infrared eye gets a far better grasp of their size than visible light-based telescopes.

In this case, NEO Surveyor concludes that the asteroid is 140 metres long. Early on, observers can't be certain where on Earth it will hit. Thankfully, your proactive observational work means that impact is 30 years away, giving you time to carefully plan a response.

There is, however, still a lot of geopolitical infighting, as nations disagree on how to handle the emergency and what to prioritise. "If I were the [US] president, I'd want to hear all ideas, no matter how crazy they might be," says Lewis. And all ideas are brought to the table, from the old standard of a kinetic impactor to giant spikes that grind up the asteroid.

Which of them are you going for?

To deflect with a KINETIC IMPACTOR, go to W

To deflect with a GRAVITY TRACTOR, go to X

To deflect using REFLECTIVE PAINT, go to Y

To disrupt using GIANT SPACE SPIKES, go to Z

W: KINETIC IMPACTOR

Flip a coin.

If **HEADS:** SEND A SCOUT FIRST

Because you have 30 years or so before impact, you can deploy a bonus mission. Spacefaring nations agree to send a reconnaissance spacecraft to check out the asteroid in advance, getting a very precise measure of its size and an idea of its internal structure.

If the asteroid is found to be a monolithic, rigid object, it will require more of a punch by a kinetic impactor to deflect it. A series of rocks weakly bound together by their own gravity, known as a rubble pile, requires a gentler prod: they are easier to deflect, but more prone to being chaotically disrupted, potentially turning a cannonball into a shotgun spray.

You discover that this particular asteroid is a rubble pile. You fly your kinetic impactor into it at a modest speed, giving it a decent wallop and deflecting it away from Earth with years to spare. Good work.

If **TAILS:** TAKE A SLIGHT GAMBLE

The world decided it wasn't worth sending a recon mission in advance. The 140-metre size of the asteroid, along with measurements of near-Earth asteroids Bennu and Ryugu that were taken (for real) in recent years, suggests that it will be a rubble pile like them – so you send the kinetic impactor in for a relatively gentle collision.

However, lacking some of the precision afforded by a recon mission, you hit the asteroid a little too emphatically and some of it breaks away. Although the surviving larger fragment is successfully deflected, a smaller one evades detection and hits Earth, blowing up above a small town.

X: GRAVITY TRACTOR

This method isn't as sci-fi as it sounds: you launch an extremely massive spacecraft towards the asteroid, using the craft's gravitational pull to tow it out of the way. It is still deflection, but it is less aggressive than an impact and unlikely to fragment the asteroid – it is also slower. By the time you construct your gleaming behemoth and fly it to the asteroid, you only have 15 years left to shift it. It isn't long enough, and you accidentally drag the space rock into a rather angry nation that was never going to be affected in the first place. YOU LOSE.

Y: REFLECTIVE PAINT

Spacefaring nations build and launch an interplanetary vandal at the asteroid to spray-paint one side of it silvery white. That boosts how much sunlight bounces off it, which gradually nudges the asteroid off its original orbit. This seems like it is going to work, but the asteroid spins quite fast, making its deflection by the sunlight hitting its shiny side somewhat unpredictable. It misses Earth on its original impact date, but it crashes into the planet two centuries later, delighting no one.

Z: GIANT SPACE SPIKES

A spacecraft rushes to greet the asteroid but stops short of doing so, instead deploying 100 huge titanium rods in its path, arrayed like a bed of nails. When the asteroid careens into them, it is shredded into a thousand pieces. All of them miss Earth, but one of the bigger shards zips off into orbit around the sun, comes back around and crashes into Mars 400 years from now. You have saved Earth, but put any future human settlement on the Red Planet in grave danger.

THE DEBRIEF

So, did you save the world, or doom it? The choices aren't as easy as they may seem at first blush. That's why it is so crucial for experts to play games like this – so they can figure out all the possible choices and potential obstacles.

The sting in any globe-defending tale is that, no matter how well-prepared spacefaring nations are, many difficult-to-control elements will factor into the effectiveness of a response. Perhaps chief among those is the possibility that spacefaring nations may act unilaterally, rather than working together – try choosing an adventure again, but this time with a group who must agree unanimously on every decision. When confronted with a real asteroid emergency, will world leaders be able to face an asteroid threat as a united front?

"I think so," says Lewis, before pausing. "I hope so." ▮

Robin George Andrews is an award-winning science journalist and author. His new book, *How to Kill an Asteroid*, is out now

Dear David

On the dark side

Our advice columnist **David Robson** has some tips for a reader keen to help a friend who is relentlessly negative about life

David Robson is an award-winning science writer and author of *The Laws of Connection: 13 social strategies that will transform your life*

Resources

An online guide by psychologist Elise Kalokerinos offers five useful steps to helping a friend in need: psyche.co/guides

The Samaritans (UK) and the 988 Lifeline (US) both offer guidance to help someone going through a mental health crisis: samaritans.org and 988lifeline.org

Dear David, an evidence-based advice column, appears monthly. Drop David a line with your social dilemmas at davidrobson.me/contact.

Next week

Stargazing at home

AFTER one of my recent book talks, an audience member described a friend who was having a hard time. Every conversation turned to the stress the friend was experiencing at work or the marital problems she was facing at home. "I want to be there for her," my new acquaintance told me. "But I don't seem to be helping."

Offering emotional support should, of course, be central to any good relationship – and until recently, I thought that patient listening was the best help that someone could offer. This is a very common opinion that draws on a "hydraulic model" of the mind. Put simply, we assume negative emotions can build up like hot gas in an engine. If we don't let them escape, we will explode – or at least suffer psychological damage from the stress. By encouraging others to talk about their unhappiness, we can open that valve, allowing them to "let off steam" and release the pain.

There's a lot of sense in this. Self-expression can sometimes feel cathartic, and it is important to feel validated for the pain that we are experiencing. Recent psychological research, however, suggests that it has its limits. If we let someone vent for too long, we may only be encouraging rumination, which will ultimately amplify their stress. For this reason, we might also help them to consider their problems from a broader perspective – a process known as reconstrual.

Ethan Kross, a psychologist at the University of Michigan, writes about this in his book *Chatter*. In one experiment, he and his team recruited more than 200 students who were in the midst of a personal conflict. Over instant messaging, some of the participants were asked to recount the upsetting situation in some detail. The rest were asked to look at the situation through a wider lens, through questions such as: "Looking at the situation, could you tell me why this event was stressful to you?"; "Have you learned anything from this experience, and if so, would you mind sharing it with me?"; and "In the grand scheme of things, if you look at the 'big picture', does that help you make sense of this experience? Why or why not?"

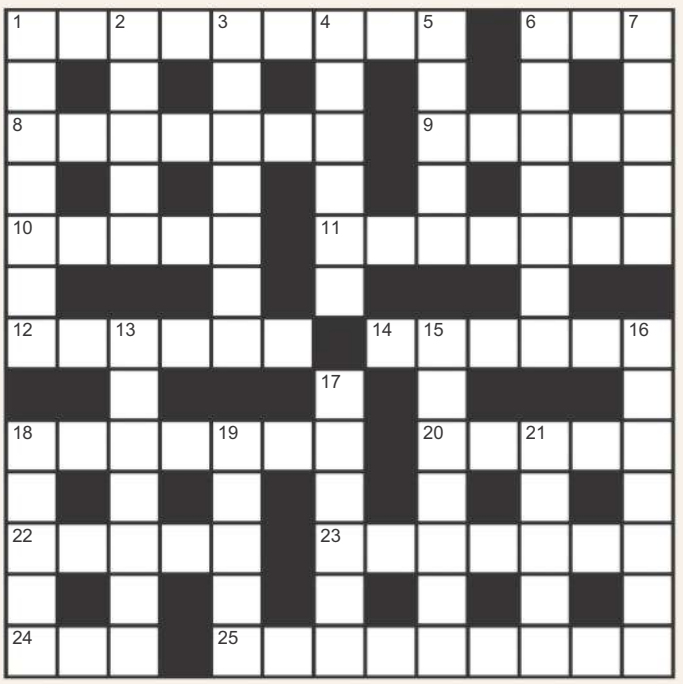
SKYNESHER/GETTY IMAGES

As Kross and his colleagues had hypothesised, these prompts encouraged the participants to look beyond their immediate pain. They felt a little distanced from the event, which reduced the stress they were feeling while producing a greater sense of closure.

Needless to say, we should practise this with sensitivity and respect. If someone's feelings are too raw, there will be little we can do to help them gain perspective. But in many cases, we may find that a small nudge towards reconstrual does wonders for their mood, and may even help them to find a long-term solution to their difficulties – while giving our own ears a rest from the endless negativity. ▮

These articles are posted each week at newscientist.com/maker

Cryptic crossword #148 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Nobleman cradling head at edge of the counter (9)
6 24-Across returned with a jack (3)
8 Depot immediately charged item (7)
9 E-sports competitor invested in mega-merger (5)
10 Lived down result of paintball hit (5)
11 Sexting between the covers with both sides of corset gone (7)
12 Genetic triplets, ones lecturing together at Cambridge? (6)
14 I committed to doing liquid dye (6)
18 Engineer penalises small error (7)
20 Walrus features animal scents: time to replace male (5)
22 Once more show breed outside India (5)
23 Before long, turn sweetheart foxy (7)
24 Ruminant 6-Across (3)
25 Host's unwelcome guest clutches good gemstone (9)

DOWN

1 Fellow stood, clumsily packing computer (7)
2 Padre prepared sheet for surgery (5)
3 Wet month is diver's ideal (7)
4 Soft dough (6)
5 Sounds like author left? Quite the contrary (5)
6 Just half-completed Minaj's new fantastical jungle setting (7)
7 Finally saw rust breaking down link (5)
13 Nearly finished job? I'd rather not say (4,3)
15 Kay's follower tucked into tuna salad spread (7)
16 Dirty birthing locale? (7)
17 You and I maintain artisan (6)
18 Transport young fish around central Peru (5)
19 Part of a procedure to contain rare throat infection (5)
21 Genre clubs provided bit of interaction after end of class (3-2)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #277
set by Bethan Ackerley

1 The portion of a scallop that is commonly eaten as seafood is what muscle?

2 Which of the following asteroids is the largest: Itokawa, Pallas or Apophis?

3 The clade Dinosauria consists of two basic groups, Ornithischia and what else?

4 In what year did Charles David Keeling begin recording atmospheric carbon dioxide levels from Mauna Loa Observatory?

5 Gems that reflect the most and brightest light are said to have what kind of lustre?

Answers on page 47

BrainTwister
set by Alison Kiddle
#45 Square differences

The number 9 can be written as a difference of two squares as $3^2 - 0^2 = 9 - 0 = 9$. Can you find a different way to express it as the difference of two squares?

Which numbers between 1 and 30 can be written as a difference of two squares?

Some numbers cannot be written in this way – can you determine which ones?

Solution next week

How brainy?

If human brains could be made larger, how much smarter could we become? And is there a practical limit to brain size?

Marc Evans
Via email
Making the human brain bigger might sound like a straightforward way to boost intelligence, but it's more complicated than that.

Intelligence isn't just about size – it is also about things like how densely packed our neurons are and how well they are connected, as well as the brain's structure and how efficiently it operates. There are also practical limits to increasing brain size.

Bigger brains require more energy, can cause complications during childbirth, generate more heat and may slow down signal transmission because of longer distances. Evolution has fine-tuned our brain size to balance cognitive abilities with these biological constraints.

So, if we are looking to enhance intelligence, it's more effective to improve how our brains function, make use of technology and create better environments, rather than just trying to increase brain size.

"As shown by Phineas Gage, having a tamping iron through the frontal lobes of your neocortex may not kill you"

James V. Stone
University of Sheffield, UK
First, does brain size matter? There is a weak correlation between human brain size and IQ, so probably. A more compelling correlation can be found by looking across mammalian species, where there is an unambiguous correlation between brain size and general cognitive ability. For example, chimpanzees cannot play checkers, which is a game that children can play.

Second, if the human brain were made larger, the consequences would depend on which parts of the brain increased in size. A part of the brain called the cerebellum constitutes around 60 per cent of the brain in the mormyrid electric fish, which relies on the structure for its impressive electric-field sensing skills.

In contrast, human competence depends on a relatively recent increase in the size of the outer layer of the brain, called the neocortex. And it matters which part of the neocortex is allowed to expand.

As tragically demonstrated by Phineas Gage (1823–1860), having a tamping iron thrust through the frontal lobes of your neocortex may not kill you, and it may not affect your intelligence, but it will destroy your ability to plan ahead or to control impulsive behaviours. So, frontal cortex matters.

Third, not all neocortical neurons are born equal. Neurons from different mammal species vary in terms of size, the speed at which they conduct electrical signals, metabolic demands, the number of connections and plasticity (ability to make new connections).

Human neurons usually have a distinct advantage for each of these variables. Anecdotal observations agree with this overall impression. After clusters of neurons were cultured in a dish and then trained to play a game of *Pong*, human neocortical neurons performed substantially better than those from a mouse.

So, assuming any increase in human brain size was actually an increase in neocortex, a bigger brain should provide a corresponding increase in ability. The difference between a normal human and a big-brained human would probably be akin to the difference between a child's view of the world compared with that of an adult. For example, a child sees the same images of the world, but fails to infer many of the hidden nuances implicit in those images.

We all know people who are clearly much smarter than ourselves; irrespective of the size of their brains, those people probably have all the properties of big-brained humans. With a bigger brain, we would see the same world as we see now, but we would understand so much more about it at any given moment.

For an insightful novel on this topic, see *Flowers for Algernon* by Daniel Keyes.

Hillary Shaw
Newport, Shropshire, UK
Making the human brain larger might not be a smart thing to do.

Say you increased its dimensions by a factor of 2. The head would now weigh eight times as much, but what supports it is the horizontal cross-sectional area of the neck and rest of the body, so you would need the body to scale up by √8, or 2.83. Then the body would be 2.83^3, or 22.7, times as massive.

The new larger organism would require about 22 times the amount of food we currently consume, maybe a little less as heat losses per kilogram of body weight are reduced. Earth would support far fewer such humans (reducing the social capital and wisdom we can collectively accumulate).

Moreover, at that size, we would probably be slow-moving, grazing herbivores, so most of our time would be spent simply searching

ANDREA QUARTARONE/SHUTTERSTOCK

Might this humpback whale in Iceland just be breaching for the fun of it?

This week's new questions

Making a splash **I enjoy diving into the sea for fun. Might whales, sharks and rays breach just because it feels good?**
Rod Kater*, Allynbrook, New South Wales, Australia*

More than four **As Earth's rotation slows, how long will it be before the rules for deciding on leap years have to be revised?**
Goronwy Humphreys*, Wallasey, Cheshire, UK*

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Tom Gauld
for New Scientist

for and consuming grazing material, which has few calories per kilogram. That would give us less time to learn new things. Large animals also have to devote more brain power to simple locomotion.

The reverse logic of this suggests that we could still be smart with smaller brains, but much smaller brains would probably lack the complexity, the number of synapse connections, to be that smart.

In other words, we have probably already hit the sweet spot where the brain is big and complex enough to make space probes, vaccines and neutron bombs, but not so big as to be unsupportable or to have its knowledge-generating functions impaired.

Greta Blake
Darlington, County Durham, UK
Yes, there is a practical limit to brain size, it's called the birth canal.

Just ask your female relatives and friends.

Which way?

Compared with a completely still universal reference point, how fast am I moving and in which direction? (continued)

Robin Maguire
Hobart, Tasmania, Australia
In terms of linear motion, who are we to say whether or not the entire universe is moving to the left at a

"When it comes to how fast you're moving and in which direction, Monty Python's *Galaxy Song* sums things up nicely"

million miles an hour, or northwards at an inch per aeon?

But for rotational displacement, the situation is entirely different. Some measurable effects depend on an absolute rate of angular velocity. If we can put a satellite into a stable circular orbit and measure its exact distance from the centre of Earth, this will enable us to calculate its orbital period in absolute terms, and thus to discover in absolute terms the true rotational speed of Earth, or the solar system, or the universe.

Common sense suggests that the universe cannot be rotating too fast, or else the centrifugal effects would mess up all those expanding universe calculations and someone would have noticed. On the other hand, might this explain some of the mysteries about dark matter?

Richard Miller
London, UK
You could name any speed you wanted (up to the speed of light) and that would almost certainly be your speed relative to something somewhere in the universe. Pick whatever reference point makes the most sense for the context, be it Earth, the sun, the Milky Way or something even larger.

Gerald Legg
Hurstpierpoint, Sussex, UK
Monty Python's *Galaxy Song* summarises things nicely. ▮

Answers

Quick quiz #277 *Answers*

1 The adductor
2 Pallas
3 Saurischia
4 1958
5 Adamantine lustre

Quick crossword #170 *Answers*

ACROSS : 7 Ricochet, **9** By half, **10** Salt, **11** *Source Code*, **12** Saturn, **14** Bessemer, **15** Rotate, **16** Herpes, **19** Parabola, **21** Huxley, **23** Stood still, **24** Deep, **25** Bounce, **26** Monorail

DOWN 1 Cicada, **2** Oort, **3** Chestnut, **4** Abacus, **5** Chickenpox, **6** Bladders, **8** Thumbs, **13** Ultrasound, **15** Reaction, **17** Ethylene, **18** Barium, **20** Oyster, **22** Emetic, **24** DERV

#44 Dice and cards *Solution*

The average for three dice is 10.5. The sum of the values on one die is 21, which is divided by 6 to give the average value for a single die as 3.5. The dice are independent, so the average value of the sum of the three is 3.5 × 3 = 10.5. For cards drawn with replacement, the answer is also 10.5 by following the same logic. If we draw three cards without replacement, there are 20 combinations (we don't care about their order, as it doesn't matter for a sum). Taking the sum of each, which ranges from 6 to 15, and finding the average, also comes out as 10.5. For an easier approach, we can note that across all 20 sums the same six numbers (1 to 6) are repeated 10 times. So the average is simply the sum of 1 to 6 multiplied by 10, then divided by 20 to give 10.5.

Hyperverbosity

Despite blowing past the word count, last week's column came in 15 lines too short, according to the editor. The only explanation we could find is that Feedback didn't use enough long words.

So, this week we are performing sesquipedalianism. Some readers may, unimaginatively, think this is pointless, but such beliefs are incomprehensibilities and those people are engaged in flagrant floccinaucinihipilification. We might even win a prize for using so many long words, which would mean that Feedback is in the state of honorificabilitudinitatibus.

Cryptocurrency career

One of the delights of the modern internet era is to be constantly told about people's exciting new jobs on social media. This happens a lot on LinkedIn, the social networking site for people who have or want jobs. Feedback isn't signed up, in a bid to retain our studied anonymity, and also because we don't want a job. Yet hundreds of millions of people are, and all of them are busy telling you about their accomplishments.

Take the cryptocurrency entrepreneur Ryan Salame, who announced his new role in October. Salame posted: "I'm happy to share that I'm starting a new position as Inmate at FCI Cumberland!" This was accompanied by a celebratory animation of a cherry falling onto a cupcake, against a background of people jumping for joy.

Feedback can't decide if this is self-deprecating humour or the most phenomenal display of arrogant disdain. After all, Salame, by his own account, "assisted Sam Bankman-Fried with the founding and creation of FTX Trading Ltd... before becoming CEO of FTX Digital Markets in [sic] September 1, 2021". In May this year, he was sentenced to seven years in prison after pleading guilty to violating political campaign finance laws and operating an illegal money-transmitting business.

On LinkedIn, under the "Experience" header, where people list jobs, Salame says he is:

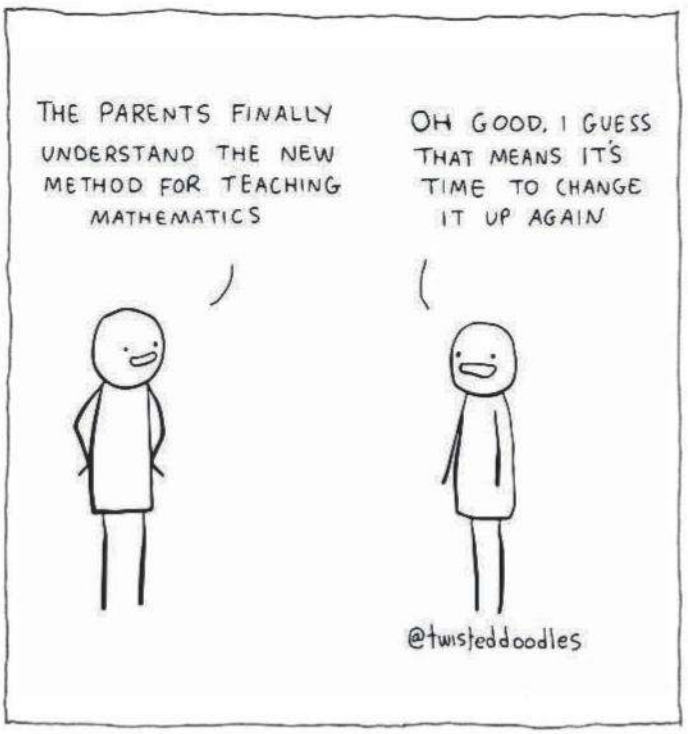
- Inmate
- FCI Cumberland · Full-time
- Oct 2024 - Oct 2024 · 1 mo
- Cumberland, Maryland, United States · On-site

He lists his job responsibilities as "cleaning and whittling".

Feedback is delighted to see a cryptocurrency felon accepting responsibility and learning the vital importance of social responsibility.

Feedback is also intrigued to note that Salame, prior to his incarceration, began operating a number of restaurants. Morbid curiosity prompts us to try one of them, but we worry that the waiters would take the food off somebody else's table in order to supply ours.

Twisteddoodles *for New Scientist*


THE PARENTS FINALLY UNDERSTAND THE NEW METHOD FOR TEACHING MATHEMATICS
OH GOOD, I GUESS THAT MEANS IT'S TIME TO CHANGE IT UP AGAIN
@twisteddoodles

Got a story for Feedback?
Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Leaders of thought

Occasionally, Feedback sees something that leaves us blinking in utter bafflement. This happened when we came across Thinkers360, which identifies itself as "the world's premier B2B thought leader, analyst and influencer community".

This appears to mean it has a list of people who purport to be experts ("thought leaders") in some field or other, who it hires out. Finally, a talent agency for people who can pontificate. Feedback is tempted to register as a thought leader in writing about nonsense.

The list of expertise claimed by Thinkers360 is truly dizzying. The company says it focuses on "cutting edge business, technology and sustainability topics", and lists no fewer than 92 fields on its site, ranging from covid-19 and autonomous vehicles to quantum computing and (of course) "Metaverse".

Intrigued, we entered the company's database, only to fall down a bottomless rabbit hole of drivel. One prospective speaker purports to be Chief Googlization Officer at the Poised for the Future Company. We aren't making this up – just search for this person online using, er, a search engine.

Anyway, in a selfless act, the company is helping experts in generative AI to get the recognition they deserve. It is offering "a unique opportunity to earn globally recognizable digital badges and credentials that validate your thought leadership and skills in this rapidly evolving field".

What this seems to mean is that, if you can talk plausibly about generative AI, you can get a picture of a black-and-white badge that says "Top 50 Thought Leader: Generative AI".

Feedback is definitely not, repeat not, encouraging readers to see if they can obtain these badges for their cats.

Category error

Feedback worries that key online services are getting worse. Case in point: on 24 October, we checked the "Science" section of Google News. Under a series of headlines about space rocks heading towards Earth, a space rock that hit Earth billions of years ago and robots inspired by extinct animals, was this: "I've slept with my girlfriend's mother, my friend's sister and even talked my THERAPIST into bed, but I can't help it".

This seemed rather out of place, and our distress was only heightened when we discovered that the story misspelled "masturbate" as "masterbate" in its URL. No prizes for guessing which tabloid newspaper was the publisher – but well done if you guessed that the story's only source was an anonymous Reddit thread. Feedback is no prude, but we aren't sure this story, fascinating as it proved to be, has been correctly categorised.

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